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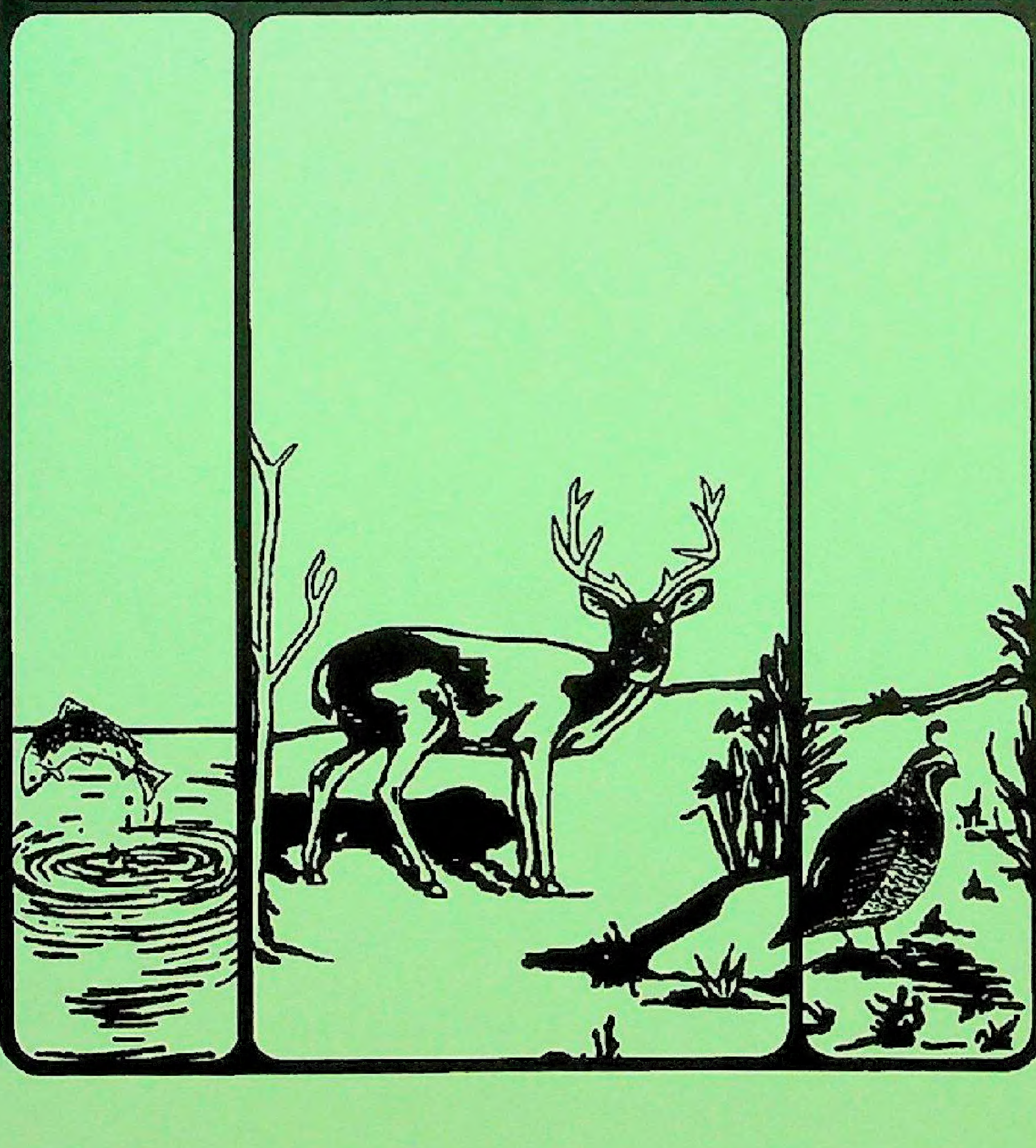

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CALIFORNIA RECREATIONAL ABALONE FISHERY CATCH AND EFFORT ESTIMATES FOR 2002 FROM A COMBINED REPORT CARD AND TELEPHONE SURVEY

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Total catch and effort were estimated for the 2002 California recreational abalone fishery, using a combination of returned report card data complimented by a telephone survey to estimate the contribution of unreturned report cards. There were 35,146 cards purchased for fishing year 2002. Abalone catch and effort were estimated at 264,130 (95% CI $\pm$ 16,823) abalone and 100,473 (95% CI $\pm$ 6,822) picker days. Catch per unit of effort averaged 2.63 abalone per picker day and 8.54 abalone per picker year. Report cards revealed that the Fort Ross area in Sonoma County and Van Damme State Park in Mendocino County provided the most abalone for pickers in 2002. Sonoma and Mendocino counties contributed almost 25% of abalone card purchasers, with 6 northern California counties accounting for over 50% of the purchasers. Telephone survey data revealed the mean number of abalone trips in 2002 as 3.1, with the mean age of pickers as 44 years. Approximately 58% of the telephone surveyed pickers accurately recalled their number of effort days and abalone taken. On average, pickers who returned their abalone report cards picked more days and took more abalone than those who did not return their cards.

INTRODUCTION

Telephone surveys have become widely used in recreational fisheries catch and effort investigations since the early 1990s. The National Marine Fisheries Service's Marine Recreational Fishery Statistics Survey for effort and catch uses both a telephone survey and an on-site access point survey (Pollock et al. 1994). More recently, California developed a modified version of the latter called the California Recreational Fish Survey (www.psmfc.org). Report cards or diaries have also been used in conjunction with telephone surveys (Pollock et al. 1994). A report card for the California recreational red abalone, *Haliotis rufescens*, fishery was established in 2000, requiring pickers to record catch and effort and return the card to the Department of Fish and Game at season's end. The return rate for 2000 was only about 24% several months after the season ended. An estimate of catch and effort based on these returns

alone would likely be biased due to avidity and other non-random factors related to those who chose to return their card versus the group that did not (Pollock et al. 1994). Therefore, a telephone survey was designed to estimate the catch and effort of the non-return group for the 2002 abalone season. The estimate was statistically combined with the actual counts from the returned report cards to produce an overall catch and effort estimate for the sport abalone fishery.

Under present circumstances, we should not anticipate the near 100% report card return rates that would obviate the need for a companion telephone survey. Despite this, our goal is to create a long-term reliable method for estimating catch and effort in the California recreational abalone fishery.

METHODS

The sampling frame used for the telephone survey consisted of the abalone report card purchaser receipt database from 2002. Preliminary report card catch and effort data from 2001 was used to calculate the range of 'n' sizes needed to produce different confidence bounds around a mean number of abalone per picker-year. The sample size required to obtain a specific confidence bound can be calculated if the variance of the population is known (Scheaffer et al. 1990). So, to calculate the sample size needed for a particular confidence interval for a normal population, set 2SE= A, where A is the desired confidence interval on each side of the mean, then:

$$n = (2SD / A)^2.$$

We used the mean, 15.4, and the variance, 285.61, from the 2001 abalone card returns to calculate the sample size needed in 2002 to estimate the number of abalone taken by anglers who did not return their abalone report cards. We decided that a confidence bound of $\pm$ 2 abalone was a reasonable goal. The sample size needed to obtain a confidence interval of $\pm$ 2 around the mean was 286.

In 2002, approximately 43% of pickers returned their cards. Based upon this ratio, about 500 completed phone interviews would be required to obtain 286 non-returnees from the list of abalone punch card purchasers. Our sampling frame included card returnees and non-returnees, with an unknown number of incorrect phone numbers and other contact problems. We called 1,064 systematically selected card purchase receipt numbers (every *nth* number) which yielded 569 completed interviews, of which 256 were non-returnees (which we accepted as a reasonable approximation of the 286 estimate), over a 10-week period beginning in April 2003.

For 2002, there were 15,004 returned cards (as of 9/2004) out of 35,146 purchased (42.7%), of these, 9297 were key-entered into a database, with 8844 having greater than zero effort (including estimated zero catches) (Table 1). Time and personnel constraints limited us to entry of a representative sample (62%) of the returned cards. Initially, all cards were entered as they came into the office, but as the number began to accelerate,

Table 1. Abalone catch and effort estimates from report card returns and telephone survey, 2002.

	Report cards returned	95% CI	Telephone survey (unreturned cards)	95% CI	Total	95% CI
Cards sold	35,146					
Number of pickers* (N)	14,329		16,597		30,926	
Sample size (n)	8,844		211		9,055	
Effort (days)	49,635	746	50,838	6,076	100,473	6,822
Mean effort (days/ picker-year)	3.46	0.052	3.06	0.336	3.25	
Catch (number of abalone)	135,873	2,052	128,293	14,771	264,130	16,823
Mean catch (abalone/ picker-year)	9.48	0.143	7.73	0.89	8.54	

* Returned and unreturned cards with > 0 effort, estimated from phone survey w/o variance.

every *nth* card was entered. In addition to providing catch and effort statistics for the non-return group, a number of key ratios could be developed from the telephone survey for refinement of the report card data (return group), including percentage of card purchasers who never used the card (zero effort) and those with a zero catch rate. The report card database program was designed to record zero catch, but does not distinguish zero catch from zero effort. Also, because effort on the report card is only recorded for a successful abalone trip, zero catch trips are not recorded and therefore the report cards underestimate effort. However, we assumed that those with at least one successful trip for the year would not have had any unsuccessful and therefore unrecorded trips. An ANOVA comparing catch rates from the telephone survey, between the return card group and the non-return group, shows a significant difference (*$P<0.05$), indicating that the returnee group did not accurately reflect the rest of the picker population. We therefore employed the phone survey to estimate the non-returnee catch and effort statistics. Variances for each estimation method, report card and telephone survey, were combined using the additive method of Pollock et al. (1994).

The telephone survey form (Fig. 1) was designed and reviewed within the Department of Fish and Game and consisted of four primary questions and seven secondary (optional) questions. The primary questions established whether or not the abalone report card had been returned prior to the time of the interview, and catch and effort information. The secondary questions concerned fishing mode and included a series of socio-economic questions to provide demographic information on the fishing population such as household income level, age and quality of fishing experience.

Introduction:
Hello. May I speak to (Mr. or Ms.) ________ please. [If not home then ask if you may try again later, do not leave a message]. *My name is __________, and I am working for the California Department of Fish and Game. You have been randomly selected from the Department of Fish and Game's abalone card purchaser database for this telephone survey. The Department is seeking valuable information regarding abalone fishing in 2002 (last year). Future abalone management rules will be based in part on the accurate reporting of abalone catch data. This information will not be used for enforcement. Would you mind answering a few questions?*

1) Did you return your pink 2002 abalone report card yet?
Whether the answer to Question 1 is yes or no, we will ask the following:

2) How many days did you fish for abalone last year (2002), if any?

Option to end interview if answer is none.

3) How many abalone did you take and retain last year, if any?
4) In what area did you take most of your abalone last year?

Mr./Ms. _______________, Would you be willing to answer a few more questions?

Continue if yes, if no, thank them and terminate interview.

Do you use swim fins in your pursuit of abalone? What percent of the time do you use a boat or kayak to get abalone?

What is your household income level [<$30,000, $30 to $60,000, $60,000 to $90,000, $90 to $120,000, >$120,000?],
How many abalone trips did you make last year?,
How much did you spend on your abalone trip(s) last year, directly related to abalone, [include gas, food, lodging, incidentals][<$100, $100 to $500, >$500]?,
How would you rate your abalone experience [excellent, good, fair, poor]?
And finally, I hope you won't mind me asking your age?

Thank you very much and good day, etc.

Figure 1. Recreational abalone telephone survey script: March 2003.

RESULTS

2002 Catch and Effort

The estimated 2002 northern California catch was 264,130 (95% CI 16,823) abalone, taken in 100,473 (95% CL 6,822) picker days of effort. There were 30,926 abalone report cards purchased and used (number estimated with greater than zero effort) in 2002, yielding an estimated 8.54 abalone per picker year (Table 1). The distribution of annual take per picker shows that over 30% of pickers took 3 or 6 abalone, multiples of the daily bag limit of 3 (Fig. 2).

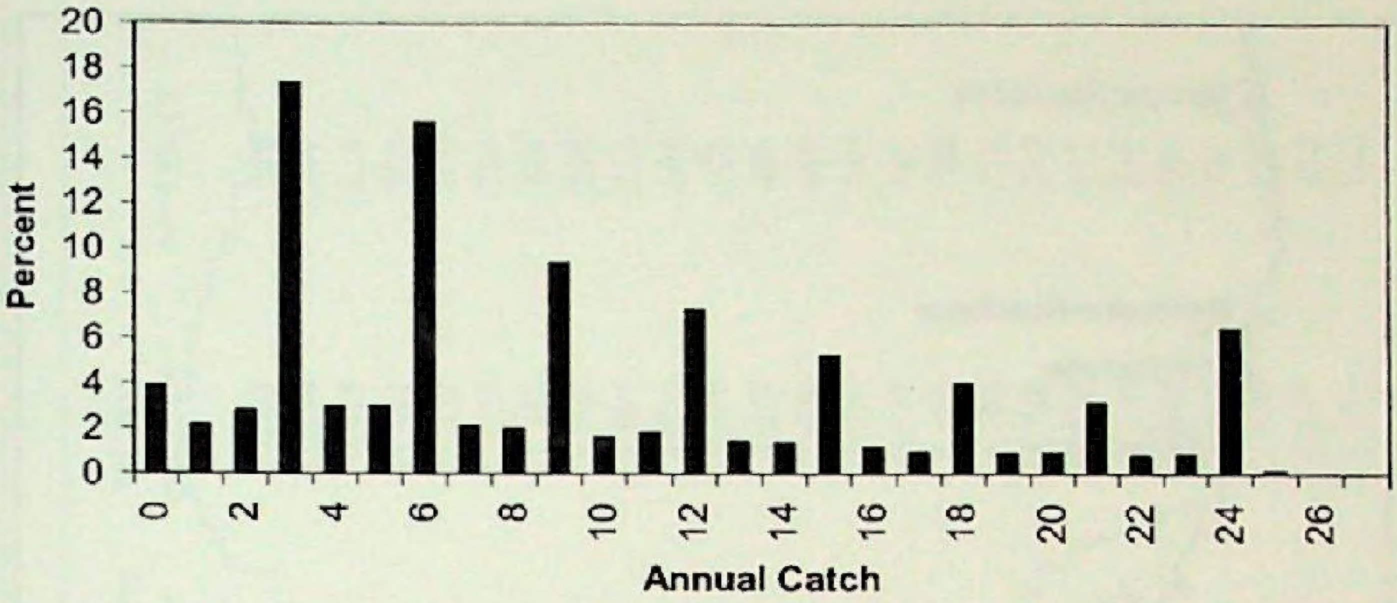

Figure 2. Frequency of annual abalone catch per picker-year for 2002.

Phone Survey Respondent Recall Accuracy

The 2002 telephone survey yielded 169 respondents whose report cards were also entered into the database. Accuracy of respondent's recall was analyzed by matching corresponding report cards with regard to effort and take. Of these 169 individuals, 47 (27.8%) matched perfectly in both effort and take. Another category of recall accuracy was conditioned on matching the report card within one unit of effort (one fishing day) and one daily bag limit (3 abalone). There were 51 (30.2%) respondents who fell into this category, for a total of 58.0%, who were reasonably accurate for activities that could have occurred more than a year prior to the interview.

The average discrepancy between recall take and report card take was 3.7 abalone, ranging from 0 to 22. The average effort discrepancy was 1.6 days fished, ranging from 0 to 41. The average take overestimate was 5.8 abalone, and the average take underestimate was 4.7 abalone. For those with no successful trips on either the card or the interview, we assumed effort recall was accurate.

Fishing Location

The advent of the abalone report card allowed not only the estimation of catch but also analysis of catch location. The 2002 report card had 56 location codes in northern California from which to choose. Both the telephone survey of all respondents to the location question and the report card database reported that 6.8% of the abalone taken were from the Van Damme State Park site in Mendocino County (Fig. 3, Table 2). A simple arithmetic expansion yields 18,044 abalone, with a partitioned 95% CI of $\pm$ 1,149 abalone. This was the second most productive location for abalone. Both the telephone survey and the report cards listed the Fort Ross area in Sonoma County as the most productive location. A simple expansion from the report card data estimates that 20,663

Figure 3. Ten highest use abalone report card sites in 2002.

Table 2. Estimated abalone recreational catch by location from report cards, 2002.

*Location code	Location	County	Abalone	Percent	Cumulative percent	**Catch expansion	***95% CI
82	Fort Ross	Sonoma	6,533	7.82	7.8	20,663	1,316
42	Van Damme SP	Mendocino	5,705	6.83	14.7	18,044	1,149
84	Reef Camp (Pedotti)	Sonoma	5,031	6.02	20.7	15,913	1,014
62	Sea Ranch	Sonoma	4,582	5.49	26.2	14,492	923
51	Arena Cove	Mendocino	4,000	4.79	31.0	12,652	806
45	Albion Head	Mendocino	3,802	4.55	35.5	12,025	766
74	Salt Pt SP	Sonoma	3,711	4.44	40.0	11,737	748
59	Other Men Co	Mendocino	2,972	3.56	43.5	9,400	599
40	Mendocino Hdlnds	Mendocino	2,844	3.41	46.9	8,995	573
80	Timber Cove	Sonoma	2,759	3.30	50.2	8,726	556
49	Elk	Mendocino	2,608	3.12	53.3	8,249	525
31	GP Mill	Mendocino	2,421	2.90	56.2	7,657	488
72	Fisk Mill Cove	Sonoma	2,231	2.67	58.9	7,056	449
32	Todd's Pt	Mendocino	2,228	2.67	61.6	7,047	449
38	Russ Gulch SP	Mendocino	2,211	2.65	64.2	6,993	445
36	Caspar Cove	Mendocino	2,112	2.53	66.8	6,680	426
52	Moat Creek	Mendocino	1,949	2.33	69.1	6,164	393
76	Ocean Cove	Sonoma	1,830	2.19	71.3	5,788	369
56	Anchor Bay	Mendocino	1,724	2.06	73.3	5,453	347
29	MacKerricher SP	Mendocino	1,620	1.94	75.3	5,124	326
35	Jughandle SR	Mendocino	1,488	1.78	77.1	4,706	300
18	Shelter Cove	Humboldt	1,349	1.62	78.7	4,267	272
78	Stillwater Cove	Sonoma	1,154	1.38	80.1	3,650	233
33	Hare Creek	Mendocino	1,150	1.38	81.4	3,637	232
89	Other Sonoma Co	Sonoma	1,054	1.26	82.7	3,334	212

Table 2 (continued)

*Location code	Location	County	Abalone	Percent	Cumulative percent	**Catch expansion	***95% CI
30	Glass Beach	Mendocino	1,045	1.25	84.0	3,305	211
44	Dark Gulch	Mendocino	934	1.12	85.1	2,954	188
39	Jack Peters Gulch	Mendocino	930	1.11	86.2	2,941	187
93	Tomales Pt	Marin	910	1.09	87.3	2,878	183
41	Gordon Lane	Mendocino	831	1.00	88.3	2,628	167
25	Westport	Mendocino	818	0.98	89.3	2,587	165
24	Abalone Pt	Mendocino	815	0.98	90.2	2,578	164
47	Navarro Ridge	Mendocino	810	0.97	91.2	2,562	163
70	Horseshoe Cove	Sonoma	766	0.92	92.1	2,423	154
66	Stewarts Pt	Mendocino	765	0.92	93.0	2,420	154
27	Kibesillah	Mendocino	713	0.85	93.9	2,255	144
86	Jenner	Sonoma	596	0.71	94.6	1,885	120
22	Hardy Creek	Mendocino	550	0.66	95.3	1,740	111
50	Pt Arena Lighthouse	Mendocino	530	0.63	95.9	1,676	107
16	Punta Gorda	Humboldt	469	0.56	96.5	1,483	94
60	Gualala Pt	Sonoma	374	0.45	96.9	1,183	75
88	Bodega Head	Sonoma	348	0.42	97.3	1,101	70
19	Other Humboldt Co	Humboldt	303	0.36	97.7	958	61
54	Saunders Landing	Mendocino	289	0.35	98.0	914	58
20	Bear Harbor	Mendocino	256	0.31	98.3	810	52
58	Robinson Pt	Sonoma	250	0.30	98.6	791	50
96	Pt Reyes	Marin	197	0.24	98.9	623	40
53	Schooner Gulch	Mendocino	186	0.22	99.1	588	37
99	Other Marin Co	Marin	151	0.18	99.3	478	30
13	Patrick's Pt	Humboldt	148	0.18	99.5	468	30
68	Rocky Pt	Sonoma	119	0.14	99.6	376	24

64	Black Pt	Sonoma	114	0.14	99.7	361	23
14	Trinidad	Humboldt	107	0.13	99.9	338	22
21	Usal	Mendocino	103	0.12	100.0	326	21
05	Crescent City	Del Norte	8	0.01	100.0	25	2
09	Other Del Norte	Del Norte	6	0.01	100.0	19	1
TOTALS			83,509	100.00		264,130	16,825

*Location code from report cards
**Catch expansion uses estimated total catch partitioned
***CI is based on CI for total catch partitioned

abalone came from this location (95% CI $\pm$ 1,316) (7.8% of report card entries listed this site vs. 9.9% from the telephone survey of all respondents). The Reef Campground site (Pedotti Ranch) is just south and contiguous with the Fort Ross site, and it is more likely that some Reef Campground pickers mark down Fort Ross as their location, rather than the converse. Taken together, report cards show that 13.8% of the abalone take comes from these two sites, which expands to 36,576 abalone (95% CI $\pm$ 2,330). More than one out of every five abalone recorded in the report card database originated from the Fort Ross-Pedotti area or the Van Damme area. Nine sites accounted for about 50% of the total catch.

Fishing Mode

Department-managed northcoast abalone on-site creel surveys have categorized abalone pickers as divers or shorepickers since 1975 by asking them whether or not they use fins in pursuit of their abalone. In the telephone survey, there were 514 respondents who answered 'yes' or 'no' to the question of whether swim fins were used in pursuit of abalone. There were four people who answered 'both'. Of the 514 'yes' or 'no' respondents, 80.5% answered 'yes' and 19.5% answered 'no'. In a winter 2000 mail survey conducted by the Department (n=283), 73.3% of respondents described themselves as divers (94.7% of this group said they used fins), while 26.7% called themselves shorepickers (12.0% of this group said they used fins).

In the winter 2000 mail survey, 23.3% said they used a boat of some kind (including kayaks). Telephone survey results showed boat use frequency as 14.8% "sometimes", 11.8% "always", and 73.3% "never". The "always" and "sometimes" groups add to 26.6%, similar to the winter 2000 mail survey result of 23.3% saying they usually use a boat.

Economic Survey

There were five questions in the economic survey that 389 interviewees (68.4%) answered all or in part. They were: annual household income level, number of abalone trips in 2002 (these could be more than 1 day in duration), money spent on all trips combined in 2002, rating the overall abalone experience (on a scale of "excellent", "good", "fair", or "poor"), and age of abalone report card purchaser (Fig. 1). The mean number of abalone trips was 3.1, with the mean age of abalone pickers at 43.8, though 81% of pickers were between 30 and 60 years old. The other questions with categorical responses and are shown in Tables 3a-e. Interestingly, 85% of respondents termed their experience "good" or "excellent", with 42% calling it an "excellent" experience. The breakdown by county of residence of 2002 abalone card purchasers, shows Sonoma and Mendocino counties contributing almost one quarter of all purchasers, and 6 northern California counties accounting for over half of the purchasers (Table 4).

Tables 3a-e. Abalone picker telephone survey socio-economic data, 2002.

Table 3a. Abalone trip frequency.

Abalone Trips		Trip category	Frequency	Percent
		0	13	3.4
Mean	3.1	1	288	75.6
SE	0.20	5	65	17.1
N	381	10	11	2.9
		15	0	0
		20	2	0.5
		25	1	0.3
		50	1	0.3
Total			381	100

Table 3b. Abalone picker age frequency.

Picker Age		Age Category	Frequency	Percent
		10	7	1.8
Mean	43.8	20	32	8.2
SE	0.58	30	110	28.4
N	388	40	122	31.4
		50	83	21.4
		60	26	6.7
		70	8	2.1
Total			388	100

Table 3c. Abalone picker household income.

Household income	Frequency	Percent
<$30,000	30	8.3
$30,000	104	28.7
$60,000	129	35.5
$90,000	68	18.7
>$120,000	32	8.8
Total	363	100

Table 3d. Abalone picker quality of experience.

Quality of experience	Frequency	Percent
Excellent	163	41.9
Good	168	43.2
Fair	44	11.3
Poor	14	3.6
Totals	389	100

Table 3a-c (continued)

Table 3c. Abalone picker trip expenditures.

Trip expense	Frequency	Percent	Permitees	Group total $
<$100	161	41.8	14,993	$749,650
$100-$500	182	47.3	16,949	$5,084,700
>$500	42	10.9	3,911	$1,955,500
Total	385	100	35,854	$7,789,850

*Permittees x midpoint of expense category

Table 4. County of residence of abalone report card purchasers, 2002.

County	Percent	Cumulative percent
Sonoma	13.73	13.7
Mendocino	8.63	22.4
Alameda	8.60	31.0
Santa Clara	8.09	39.1
Sacramento	6.96	46.0
San Mateo	5.60	51.6
San Francisco	5.47	57.1
Contra Costa	5.46	62.5
Humboldt	4.49	67.0
Marin	4.41	71.4
Napa	3.03	74.5
Solano	2.89	77.4
Butte	2.73	80.1
San Joaquin	2.34	82.4
Santa Cruz	2.32	84.7
Placer	1.81	86.6
Yolo	1.65	88.2
Shasta	1.58	89.8
Los Angeles	1.10	90.9
San Diego	0.98	91.9
Sutter	0.95	92.8
Nevada	0.86	93.7
Stanislaus	0.68	94.4
San Luis Obispo	0.66	95.0
Orange	0.55	95.6

Santa Barbara	0.45	96.0
Plumas	0.40	96.4
Fresno	0.37	96.8
Monterey	0.37	97.2
Ventura	0.31	97.5
Del Norte	0.29	97.8
El Dorado	0.24	98.0
Yuba	0.24	98.2
Amador	0.21	98.5
San Benito	0.21	98.7
Tuolumne	0.21	98.9
Calaveras	0.19	99.1
Lake	0.13	99.2
Riverside	0.13	99.3
Inyo	0.11	99.4
Lassen	0.11	99.5
Tulare	0.11	99.7
Kern	0.06	99.7
Kings	0.06	99.8
San Bernardino	0.06	99.9
Tehama	0.06	99.9
Madera	0.03	100.0
Merced	0.03	100.0
Imperial	0.02	100.0
Total	100.0	

DISCUSSION

Karpov[1] (1992) estimated that 80,405 ($\pm$ 24,092) pickers made 134,996 ($\pm$ 34,082) trips for 433,069 ($\pm$ 110,222) red abalone (the daily bag limit was four at that time and there was no annual limit, 2002 limits were 3 daily and 24 annually) in the 1989 combined creel and telephone survey (the last survey completed prior to this one). Catch per picker year was estimated at 5.39 abalone. The 1988 combined creel and telephone survey estimated that 80,891 ($\pm$ 24,301) pickers made 162,127 ($\pm$ 34,690) trips for 450,747 ($\pm$ 107,969) red abalone (Karpov[2] 1991). Catch per picker year was estimated

[1]Karpov, K.A. 1992. A combined telephone and creel survey of the red abalone, *Haliotis rufescens* (Swainson), sport fishery in California from Monterey to the Oregon border, April through November 1989. California Department of Fish and Game, Marine Resources Administrative Report 92-3.

[2]Karpov, K.A. 1991. A combined telephone and creel survey of the red abalone, *Haliotis rufescens* (Swainson), sport fishery in California from Monterey to the Oregon border, April through November 1988. California Department of Fish and Game, Marine Resources Administrative Report 91-2.

Table 5. Comparison of abalone fishery catch and effort estimates: 1988, 1989 and 2002.

Year	Number of pickers	Number of picker-days	Mean abalone/ picker-year	Total number of abalone taken
1988	80,891	162,167	5.57	450,747
1989	80,405	134,996	5.39	433,069
2002	30,926	100,473	8.54	264,130

at 5.57 abalone. This compared with 8.54 red abalone per picker-year estimated for the 30,926 abalone card purchasers with greater than zero effort in 2002 (Table 5). A comparison of confidence limits between the 1988 and 1989 estimates and the 2002 estimate shows the value of the combined report card and telephone survey targeting abalone card purchasers, versus a general telephone directory frame-based phone survey in which both fishing and non-fishing households are contacted. The latter was characterized by a very small sample size of abalone pickers and relied on bootstrapping to estimate variances. Confidence intervals for the 1988 and 1989 abalone catch estimates ranged from $\pm$ 24.0% to $\pm$ 25.5%, while the 2002 CIs were within 6.4% of the estimate.

While the point estimates of number of pickers in 1988 and 1989 were remarkably similar, the 2002 estimate is only 38.5% of the 1989 estimate. The lower confidence bound of the 1989 estimate is almost twice the 2002 estimate as well. So, the appearance of a large reduction in northern California abalone effort during this time period seems to be accurate. In 1989, an estimated 30.1% of the abalone pickers were shorepickers, while the estimate in 2000 from a mail survey was 26.7%, and by the 2002 telephone survey, shorepickers made up an estimated 19.5%. The reduction in the proportion of shorepickers in the fishery is likely due to a combination of factors, including the fact that divers are not as dependent as shorepickers on low tides to hunt for abalone, and divers have much larger reef areas accessible to them compared to shorepickers, even at minus tides. In addition, shorepicker catch and effort data from 1989 to 2000 showed an increased take of abalone from more remote populations at Sonoma County and southern Mendocino County creel survey sites, indicating a probable depletion of abalone near access points for shorepickers (ARMP[3]).

It is useful to place the abalone take in a specific area in the context of what is known about local populations. Creel-type surveys combined with subtidal SCUBA surveys determined that about 33.3 hectares of shallow (< 5.5 m) reef habitat are available to abalone pickers in the Van Damme area. The 1999 Department subtidal abalone survey determined there were about 5,000 legal sized abalone per hectare, for a population estimate of about 166,550 red abalone (J. Kashiwada, California Department of Fish and Game, personal communication). The estimate of 18,000 legal sized (> 178 mm) abalone

[3]California Department of Fish and Game. 2005. Abalone Recovery and Management Plan. Sacramento, California.

taken from Van Damme SP in 2002 would represent about 10.8% of this population. Whether this number is sustainable is questionable give the slow growth and erratic recruitment patterns of red abalone (Haaker et al., 1998, Karpov et al. 1998).

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These estimates could not have been made without the help of numerous individuals. Most especially, C. Skeen diligently key-entered every one of the over 9,000 abalone report cards used in this analysis and made a high percentage of the over 1,000 calls in the telephone survey. J. Kashiwada and L. Johnson assisted in the cataloging of report cards. J. Ramsay and W. Stroud also made many of the telephone survey calls.

LITERATURE CITED

Haaker, P.L., D.O. Parker, K.C. Barsky, and C.S.Y. Chun. 1998. Growth of the red abalone, *Haliotis rufescens* (Swainson), at Johnsons Lee, Santa Rosa Island, California. Journal of Shellfish Research, Vol. 17, No. 3: 747-753.

Karpov, K.A., P.L. Haaker, D. Albin, I.K. Taniguchi, and D. Kushner. 1998. The red abalone, *Haliotis rufescens*, in California: importance of depth refuge to abalone management. Journal of Shellfish Research, Vol. 17, No. 3: 863-870.

Pollock, K.H., C.M. Jones, and T.L. Brown. 1994. Angler Survey Methods and Their Applications in Fisheries Management. American Fisheries Society Special Publication 25.

Scheaffer, R. L., W. Mendenhall, and L. Ott. 1990. Elementary Survey Sampling. PWS-Kent Publishing Co., Boston, 4th Ed., 390pp.

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A SURVEY OF THE FISHES OF THE CABRILLO NATIONAL MONUMENT, SAN DIEGO, CALIFORNIA

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ABSTRACT

During 2004, the nearshore fish assemblage of the Cabrillo National Monument (San Diego County, California) was surveyed as a means of creating an inventory of the nearshore fish species utilizing the area, as well as to examine the role of human disturbance (trampling) on the tide flat ichthyofauna. Survey techniques included visual census by SCUBA divers, gill nets, fish traps, and tide pool collections. Overall, 47 species from 20 families were collected. No quantitative difference was found in the tidepool fish assemblage between each of three "use zones" which vary in the amount of human impact. A no-take zone for invertebrates and kelp, the Cabrillo National Monument is one of California's southernmost reserves, and as such may play an important role in the community dynamics of the ichthyofauna of the region.

INTRODUCTION

With the documented reduction in global biodiversity as a direct result of human-induced changes (e.g., Stenack 1998), it has become increasingly apparent that the value of no-take marine reserves is rapidly increasing. Protecting not only single, charismatic species, marine reserves and marine protected areas serve to enhance ecosystem function by protecting and reducing damage to critical habitat and limiting or restricting the take of organisms. These practices allow systems to return to stable states that may resemble pre-exploited conditions. While many marine protected areas today are relatively new (ca 20 years old), case studies exist that document increases in size and abundance of species targeted by fisheries following the establishment of the reserve (Roberts 1995; Russ and Alcala 1996).

Assessing the effectiveness of marine protected areas provides a unique challenge as often there is no baseline data available for populations prior to their exploitation.

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While any data gathered under the current conditions may be a baseline for future studies, they fail to capture the prior community structure that may have been quite different from that of today (Dayton et al. 1998; Baum and Myers 2004). However, given the relative paucity of data available for reconstructing past community structure, it is an unavoidable reality that present-day conditions represent the best available data for generating baselines, and every effort should be made to establish such pseudo-baselines in order to address the effects of any marine protected area. At the very least, this requires a general knowledge of the species composition within a designated reserve and any direct and obvious human influences.

Established as a national monument in 1913, the Cabrillo National Monument (CNM) is comprised of a variety of submerged habitats that include a transient sandy beach, a relatively large tide flat, and submerged rocky reef habitat. Each of these habitats plays an important role in the community structure of the nearshore marine fishes within the boundaries of the reserve. Although this park is not a designated no-take zone for fishes, it is protected from invertebrate collection. As with most reserves in California, and despite the importance of the CNM as a marine habitat, the body of knowledge pertaining to the fish community within the enclosed area is relatively sparse.

The location of the CNM on the south-western side of Pt. Loma makes it one of California's southernmost marine reserves (Figure 1, McArdle 1997). It is a major attraction for both research scientists and the public as one of the largest and most easily accessible tide flats in San Diego. The park covers roughly 65 hectares and the tide flat portion is visited by nearly 100,000 people per year (B. J. Becker, NPS, personal commication). The CNM is divided into "use zones" in order to minimize the impact of trampling throughout the park. These zones vary from completely unrestricted (Zone 1) to zero public entry (Zone 3). The oceanic boundary extends 275 m offshore from mean low-low tide.

Recently, evaluations of the effectiveness of marine reserves in the San Diego region have been undertaken (Craig et al. 2004; Parnell et al. 2005). As a means of contributing to the growing body of knowledge for fishes of San Diego marine reserves, and to ongoing surveys of other organisms within the CNM, multiple sampling techniques were used to compile a list of intertidal and subtidal fish species that utilize the habitat enclosed by its boundaries. While intertidal fish communities in the San Diego area have been previously examined (Davis 2000; Davis 2001), none has explicitly examined the community within the CNM. Given that the park varies in terms of the level of trampling, it provides a unique setting to test its effects on the intertidal fish community. While several studies have indicated negative effects of trampling on invertebrate and algal cover (e.g., Adessi 1994, Brown and Taylor 1999, Murray et al. 1999, Engle and Davis 2000, Smith and Murray 2005), none have examined the role of human disturbance on diversity and density of tide pool fishes. Despite the lack of protection from fishing, this information should provide useful insights for resource managers and marine ecologists who seek to understand the integrated response of marine communities to natural and anthropogenic disturbances within and around reserve areas.

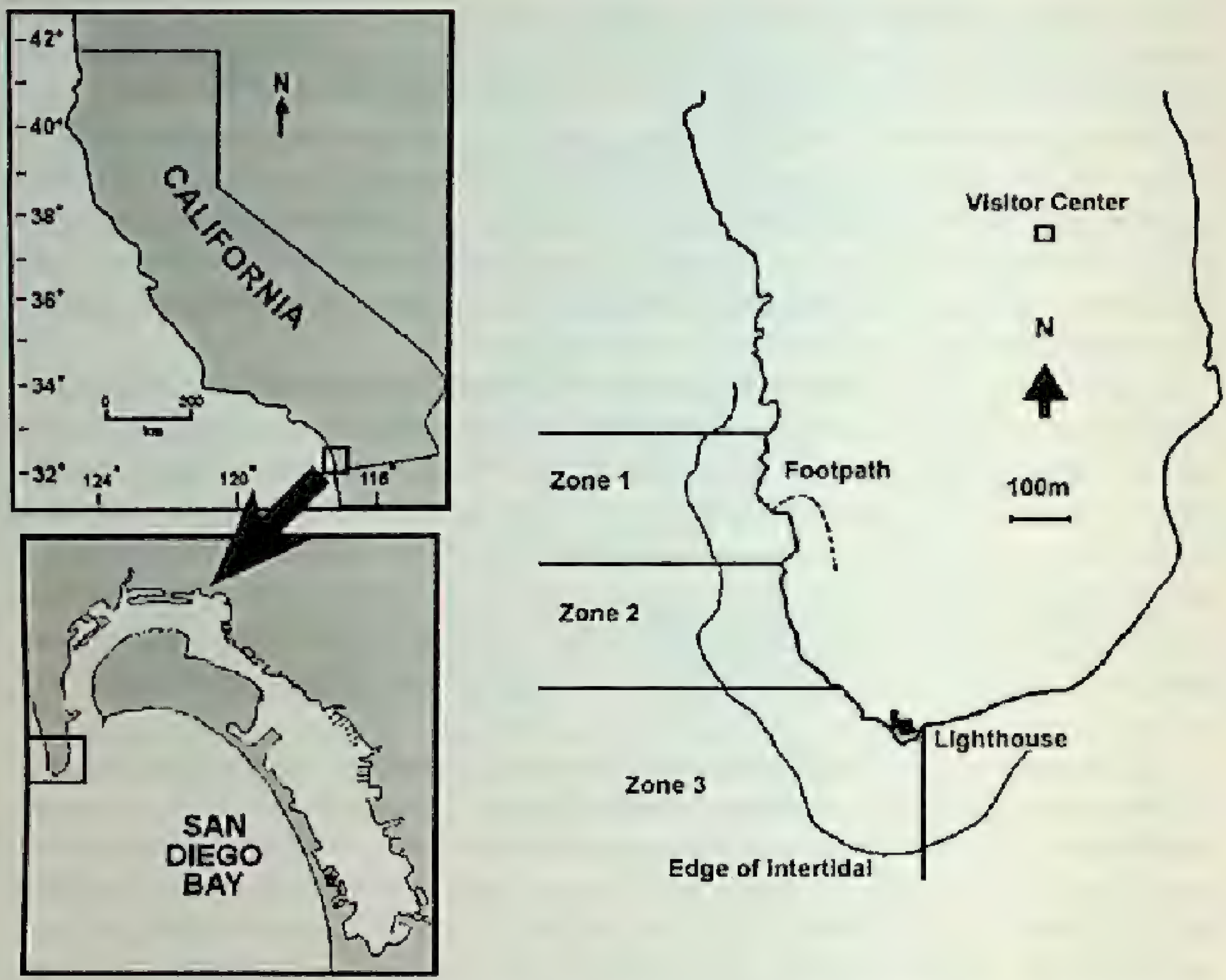

Figure 1. Map of the Cabrillo National Monument, San Diego, California. Zones are divided based on human use and are subject to various levels of trampling. Zone 1 = high use, Zone 2 = intermediate, and Zone 3 = no use (research only). Area enlarged is the boxed zone of the lower left panel.

METHODS

A variety of methods was used to census the fishes within the CNM as a means of capturing both resident fishes that remain on the tide flat, and transient fishes that may utilize portions of the reserve that are only submerged during high tide. These included 45.5 m long x 2.5 m high gill nets with variable mesh (2.5 cm, 3.8 cm, and 5 cm), minnow traps, 50 m diver surveys counting fishes in a 1 m window, visual tide pool surveys, and non-selective removal of fishes in tide pools using the natural product clove oil (Terry and Stephens 1976; Stephens et al. 1984; Stephens et al. 1994; Griffiths 2000). For each use zone, three minnow traps, one gill net, two diver transects, and three surface visual transects were accomplished on a quarterly basis (February, June, July, and December). Gill nets and fish traps were set for a period of 12-16 hr overnight in 4-8 m of water following the method of Pondella and Allen (2000).

In each zone, two isolated and randomly selected tide pools were inoculated with

clove oil as a means of removing all cryptic fishes. Tide pool sampling occurred on a quarterly basis (January, April, July, and November). In each zone, one pool was selected from the mid-intertidal, and one pool was selected from the low-intertidal. Tide pools ranged in size from 0.5 m^2 to 3.9 m^2, and were no more than 36cm deep.

All fish were measured to the nearest 5 mm in the field or to the nearest 0.1 mm in the laboratory for intertidal species. Fishes were weighed to the nearest 5 g aggregate weight in the field or to the nearest 0.1 g in the laboratory for intertidal species. Live fishes from the gill net surveys were returned to the habitat to minimize disturbance, while all other individuals were retained in the laboratory, representatives of which were deposited at either the Occidental College research collection, the Scripps Institution of Oceanography Marine Vertebrates Collection (SIOMVC), or the Cabrillo National Monument teaching and research collection.

To evaluate human induced impacts (trampling) on tide pool fishes, total abundance, richness, density, and diversity (Shannon-Wiener Index: H') were calculated for the entire survey period for each zone. Additionally, mean density values per zone were calculated and tested for significant differences. Raw density data from zones two and three were not found to be distributed normally (Komolgrov-Smirnoff test; KS = 0.3078 and 0.3337, P = 0.0247 and 0.00091, respectively). Density data were therefore log transformed (ln) to normalize the data (KS = 0.7950, 0.1484, 0.1336, Zone 1, 2, and 3, respectively; $P > 0.10$ for all values) and make it suitable for parametric (ANOVA) comparisons.

RESULTS

Overall, 47 species from 20 families were recorded within the CNM (Table 1). The gill nets, diver transects, and clove oil stations were the most effective sampling strategies, capturing 100% of the total richness. The fish traps were inefficient at catching any species other than silversides (e.g., *Atherinopsis californiensis*). The fish traps were therefore abandoned following the first quarter. The tide pool fishes included 12, mostly cryptic, species including members of the Blenniidae, Clinidae, Cottidae, Gobiesocidae, and Kyphosidae. Sub-tidal fishes accounted for the remaining 36 species and represented several common marine families (Table 1).

The most abundant intertidal fish species was the wooly sculpin, *Clinocottus analis* (Cottidae), followed by the spotted kelpfish, *Gibbonsia elegans* (Clinidae), and juveniles of the opaleye, *Girella nigricans* (Kyphosidae)(Table 2). Overall density of tide pool fishes in the CNM was 8.22 fish/m^2. Mean density of intertidal fishes was highest in the intermediate use zone (Zone 2), followed by the no use, and high use zones (Zones 3 and 1, respectively; Figure 2). Overall density, however, was highest in Zone 2, followed by zone 1 and Zone 3 (Table 3). No significant difference was found for mean density values among the use zones using the log transformed datasets (ANOVA F = 0.1582, P = 0.8547). Species richness was highest in the intermediate zone (R = 9), followed by the high use (R = 8) and no use (R = 5) zones (Table 2). Shannon-Wiener diversity indices were highest in the high use zone, followed by the intermediate and no use zones (Table 3).

Table 1. List of fishes collected in the Cabrillo National Monument in 2004. Species are listed in taxonomic order following Nelson (1994), and common name follows scientific name following Nelson et al. (2004). Authorship of species follows Eschmeyer (1998).

Scientific Name	Common Name
Heterodontidae-bullhead sharks	
Heterdontus francisci (Girard 1855)	horn shark
Triakidae-houndsharks	
Mustelus henlei (Gill 1863)	brown smoothound
Triakis semifasciata Girard 1855	leopard shark
Rhinobattidae-guitarfishes	
Rhinobatos productus Ayres 1854	shovelnose guitarfish
Batrachoididae-toadfishes	
Porichthys myriaster Hubbs and Schultz 1839	specklefin midshipman
Atherinnopsidae-neotropical silversides	
Atherinops affinis (Ayers 1860)	
Atherinopsis californiensis Girard 1854	jacksmelt
Leuresthes tenuis (Ayres 1860)	California grunion
Scorpaenidae-scorpionfishes	
Scorpaena gutatta Girard 1854	California scorpionfish
Sebastes atrovirens (Jordan and Gilbert 1880)	kelp rockfish
Sebastes rastrelliger (Jordan and Gilbert 1880)	grass rockfish
Cottidae-sculpins	
Clinocottus analis (Girard 1858)	wooly sculpin
Scorpaenichthys marmoratus Girard 1854	cabezon
Serranidae-sea basses	
Paralabrax clathratus (Girard 1854)	kelp bass
Paralabrax nebulifer (Girard 1854)	barred sand bass
Carangidae-jacks	
Trachurus symmetricus (Ayers 1855)	jack mackerel
Haemulidae-grunts	
Anisotremus davidsonii (Steindachner 1876)	sargo
Xenistius californiensis (Steindachner 1876)	salema
Kyphosidae-sea chubs	
Girella nigricans (Ayres 1860)	opaleye
Hermosilla azurea Jenkins and Evermann 1889	zebraperch
Medialuna californiensis (Steindachner 1856)	halfmoon
Sciaenidae-drums	
Atractoscion nobilis (Ayres 1860)	white seabass
Cheilotrema saturnum (Girard 1858)	black croaker
Menticirrhus undulatus (Girard 1854)	California corbina
Seriphus politus Ayres 1860	queenfish
Embiotocidae-surfperches	
Brachyistius frenatus Gill 1862	kelp perch

Embiotoca jacksoni Agassiz 1853	black perch
Hyperprosopon argenteum Gibbons 1854	walleye surfperch
Hypsurus caryi (Agassiz 1853)	rainbow seaperch
Micrometrus minimus (Gibbons 1854)	dwarf perch
Phanerodon furcatus Girard 1854	white seaperch
Rhacochilus toxotes Agassiz 1854	rubberlip seaperch
Rhacochilus vacca Girard 1855	pile perch
Pomacentridae-damselfishes	
Hypsypops rubicundus (Girard 1854)	garibaldi
Labridae-wrasses	
Halichoeres semicintus (Ayers 1859)	rock wrasse
Oxyjulis californica (Günther 1861)	señorita
Semicossyphus pulcher (Ayres 1854)	California sheephead
Clinidae-clinids	
Gibbonsia elegans Hubbs 1927	spotted kelpfish
Gibbonsia metzi Hubbs 1927	striped kelpfish
Heterostichus rostratus Girard 1854	giant kelpfish
Paraclinus integripinnis (Smith 1880)	reef finspot
Blenniidae-combtooth blennies	
Hypsoblennius gilberti (Jordan 1882)	rockpool blenny
Hypsoblennius jenkinsi (Jordan and Evermann 1896)	mussel blenny
Gobiescodiae-clingfishes	
Gobiesox rhessodon Smith 1881	California clingfish
Rimicola eigenmanni (Gilbert 1890)	slender klingfish
Gobiidae-gobies	
Typhlogobius californiensis Steindachner 1879	blind goby
Sphyraenidae-barracudas	
Sphyraena argentea Girard 1854	Pacific barracuda

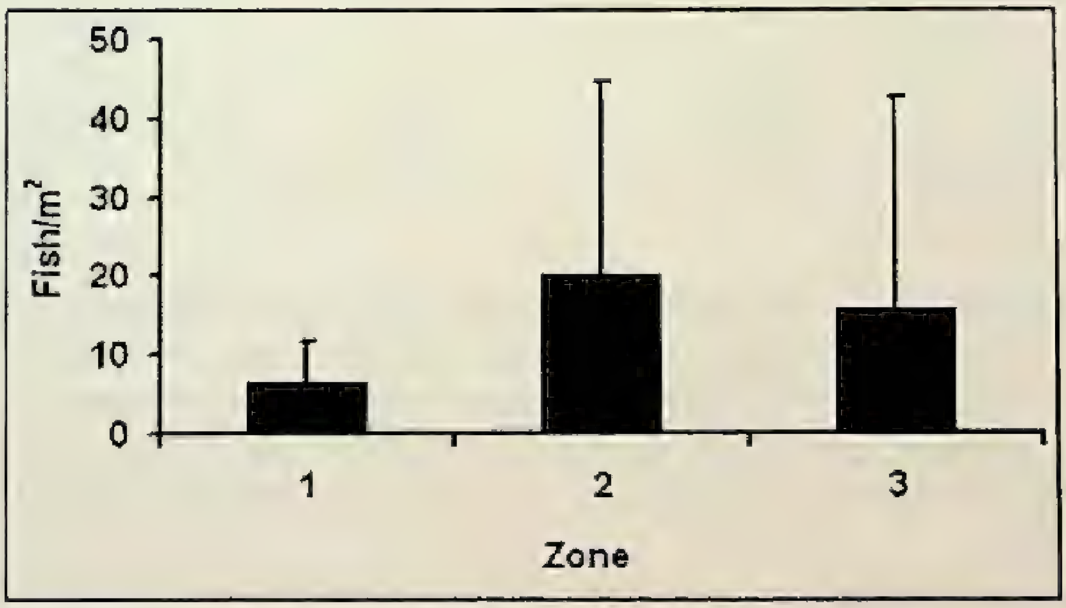

Figure 2. Mean density values for tide pool fishes sampled in the Cabrillo National Monument. Values are shown as individual fish per meter squared. Zones are as in Figure 1. Values are not significantly different than would be expected by chance (Kruskal-Wallace = 0.2850, P = 0.8672). Error bars are one standard deviation.

Table 2. Species and abundance of fishes collected in tidepools at the Cabrillo National Monument, San Diego, Calfornia. Species are listed in order of decreasing abundance.

	Quarter				
Species	1	2	3	4	Total
Clinocottus analis	63	34	32	11	140
Gibonsea elegans	27	6	2	2	37
Girella nigricans	7		22		29
Hypsoblennius gilberti	5	4	7	9	25
Gobiesox rhessodon	6	1	4	2	13
Paraclinus integripinnis	8	3			11
Leuresthes tenuis			6		6
Hypsoblennius jenkinsi				5	5
Medialuna californiensis			4		4
Gibonsea metzi	3				3
Rimicola eigenmani	3				3
Typhlogobius californiensis		1			1
Total	122	49	77	29	277

Table 3. Overall abundance, richness, density, and diversity of tide pool fishes in the Cabrillo National Monument in 2004. Zone 1 is the high use area, Zone 2 intermediate, and Zone 3 no-use area.

	Zone		
	1	2	3
Abundance	90	107	80
Richness	8	9	5
Density	7.97	9.91	6.90
Diversity (H')	1.63	1.56	0.97

Gill net catches were comprised of 29 species of common California fishes (Table 4). The most common species taken by the gill nets was the salema, *Xenistius californiensis* (Haemulidae), followed by the queenfish, *Seriphus politus* (Sciaenidae), and the leopard shark, *Triakis semifasciata* (Triakidae)(Table 4). Catch per unit effort (CPUE) ranged from 4 fish/net in December to 64.7 fish/net in June (mean = 27.5 fish/net)(Table 4).

The most common species seen during the diver transects within the CNM was the señorita, *Oxyjulis californicus* (Labridae), followed by the opaleye, *Girella nigricans* (Kyphosidae), and the garibaldi, *Hypsypops rubicundus* (Pomacentridae)(Table 5). Density of fishes ranged from 0.33 fish/m^2 to 2.57 fish/m^2 (mean 0.974; standard deviation = 0.571).

Table 4. Species, abundances, catch per unit effort (CPUE) by quarter sampled and overall for fishes collected in gill nets at the Cabrillo National Monument in 2004. Species are listed in decreasing order of abundance.

	Quarter				
Species	1	2	3	4	Grand Total
Xenistius californiensis		41	23		64
Seriphus politus		39	21		60
Triakis semifasciata	3	17	11	4	35
Umbrina roncador		13	13		26
Cheilotrema saturnum		16	6		22
Paralabrax clathratus	2	12	5	2	21
Girella nigricans		7	13		20
Anisotremus davidsonii		7	7		14
Atractoscion nobilis	4	6			10
Atherinopsis californiensis	1	7		1	9
Embiotoca jacksoni		4	4		8
Halichoeres semicincta		6		1	7
Hypsurus caryi	1	2	2	2	7
Hyperprosopon argenteum	3	2			5
Rhinobatos productus		2	1		3
Semicossyphus pulcher	1	1		1	3
Hermosilla azurea			2		2
Sebastes rastrelliger		1		1	2
Sphyraena argenteum		2			2
Heterdontus francisci		1			1
Heterostichus rostratus		1			1
Menticirrus undulata		1			1
Mustelus henlei		1			1
Paralabrax nebulifer		1			1
Porichthys notatus		1			1
Scorpaena gutatta		1			1
Scopaenichtys marmoratus		1			1
Sebastes artrovirens	1				1
Trachurus symetricus		1			1
Total	16	194	108	12	330
CPUE	5.3	64.7	36.0	4.0	27.5

Table 5. Species and abundances of fishes observed by diver transects in the Cabrillo National Monument, San Diego, California. Species are listed in decreasing order of abundance.

Species	Quarter 1	2	3	4	Total
Oxyjulis californica	384	311	336	235	1266
Girella nigricans	141	121	136	46	444
Hypsopops rubicundus	23	61	71	33	188
Embiotoca jacksoni	58	52	30	23	163
Paralabrax clathratus	17	25	37	14	93
Medialuna californiensis	8	32	24		64
Semicossyphus pulcher	4	12	27	9	52
Brachyistius frenatus	33		16		49
Heterostichus rostratus	11	12	9		32
Rhacochilus toxotes	5	2	11	6	24
Micrometrus minimus	17		4		21
Rhacochilus vacca	3	3	11		17
Halichoeres semicincta	2	9			11
Phanerodon furcatus	10				10
Cottidae sp.	1				1
Grand Total	717	640	712	366	2435

DISCUSSION

The fish assemblage of the CNM is a typical rocky-shore fish assemblage for southern California mainland habitats (Pondella and Allen 2000; Craig et al. 2004; Stephens et al. 2005). The overall richness (R = 47) was found to be comparable with other similar habitats in the San Diego region (Craig et al. 2003; Craig et al. 2004, Pondella et al. 2006). While the number of species was comparable, the density and abundance of these species was relatively low in comparison to other localities. For example, using the same gill net methods, Craig et al. (2004) found a mean CPUE of 193.25 fish/net at the nearby Scripps Coastal Reserve compared to the mean CPUE of 27.5 fish/net at CNM (Table 4). This high diversity, low-density pattern may be a result of the lack of high relief habitat associated with the CNM, which limits the density of many reef fishes. Additionally, the high energy environment surrounding the CNM results in a lack of sand accumulation on the hard pan substrate making it unsuitable for many flatfish species which are found in high densities at nearby localities (e.g., the speckled sanddab, *Citharichthys stigmaeus*; Craig et al. 2004). The placement of the CNM at the mouth of San Diego Bay provides easy access to many recreational and sport fishing vessels, hence fishing pressure may limit the abundance of target species such as the kelp bass, *Paralabrax clathratus*, the California sheephead, *Semicossyphus pulcher*, and the white seabass, *Atractoscion nobilis*.

Compared with previous surveys of intertidal fishes in the San Diego region, our survey found relatively few species. Davis (2000) reported 15 species over a survey of 105 tide pools from 1996 to 2000. Nine of those 15 species were listed as uncommon, and were present in fewer than 4 sampling months. Of the common species listed by Davis (2000), our survey found similar composition of the dominant species (*Clinocottus analis*, *Gibbonsia elegans*, and juvenile *Girella nigricans*). The lack of agreement in overall species richness is most likely a rarefaction effect as the length and intensity of the previous surveys far exceeded the present study.

No significant difference in density of fish was found among the varying use zones despite a somewhat striking qualitative difference (Figure 2, Table 3). The impact of trampling from human activities has rarely been examined for intertidal fishes. The high use zone (Zone 1) at CNM, where the mean density was lowest, had the highest diversity value (Mean Density = 6.6 fish/m^2, H' = 1.63; Table 3, Figure 2). Although the density was low, species were distributed more evenly. The lower density may be an artifact of larger pools being a target of human interest in the high use zone and a resulting behavioral response by the fishes avoiding these areas. However, it is interesting to note that the zone with the least human disturbance (Zone 3) also had the lowest species richness. This may be an artifact of disturbance caused by intense wave action as zone 3 is situated in the most exposed portion of the park.

The three zones also included species that are both resident and transient species on the tide flat (Table 1). While 11 of the 12 species found in the tide pools may be considered resident, the remaining species collected by the gill nets and observed by the diver surveys are most likely utilizing the tide flat habitat as foraging area during high tides, highlighting the importance of this habitat for more than just intertidal species (Gibson 1999).

With the lack of earlier, baseline data, it is nearly impossible to address the effectiveness of the CNM as a marine reserve for fishes. In comparison to other nearby habitats in San Diego, the CNM appears to harbor similar numbers of species at somewhat lower densities (Craig et al. 2004). This may indicate that a synergistic effect of fishing pressure and habitat protection within the reserve serves to maintain diversity, yet limit density. The value of the CNM as a marine protected area, however, should not be overlooked. The reserve harbors many non-target species that rely upon the tide flat habitat for reproduction, foraging, and protection either as permanent residents or transients. These habitats are often destroyed or harmed by fisheries activities and coastal development, thus the protection of this habitat by the boundaries of the CNM is undoubtedly critical in the success of the species which utilize it. Reserves such as the CNM are essential to protect this and other critical habitats, and therefore should not only be maintained, but expanded. Such expansion will serve only to enhance the protection afforded to both target and non-target species and ultimately bolster the success of marine communities.

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LITERTURE CITED

Adessi, L. 1994. Human disturbances and long term changes on a rocky intertidal community. Ecological Applications 4:786-797

Baum J. K., and R. A. Myers. 2004. Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Ecology Letters 7 (2): 135-145.

Brown P. J., and R. B. Taylor. 1999. Effects of trampling by humans on animals inhabiting coralline algal turf in the rocky intertidal. Journal of Experimental Marine Biology and Ecology 235:45-53.

Craig, M.T., P. A. Hastings, and P. K. Dayton. 2003. The nearshore fish assemblage of the San Diego/La Jolla Ecological Reserve. (Abstract). Bulletin of the Southern California Academy of Sciences Supplement.

Craig, M. T., F. J. Fodrie, and P. A. Hastings. 2004. The nearshore fish assemblage of the Scripps Coastal Reserve. Coastal Management 32: 341-351.

Dayton, P. K., M. J. Tegner, P. B. Edwards, and K. L. Riser. 1998. Sliding baselines, ghosts, and reduced expectations in kelp forest communities. Ecological Applications 8 (2): 309-322.

Davis, J. L. 2000. Changes in a tidepool fish assemblage on two scales of environmental variation: Seasonal and El Niño Southern Oscillation. Limnology and Oceanography 45(6):1368-1379.

Davis, J. L. 2001. Diel changes in habitat use by two tidepool fishes. Copeia 2001(3):835-841.

Engle, J. M., and G. E. Davis. 2000. Ecological condition and public use of the Cabrillo National Monument intertidal zone, 1909-1995. U. S. Department of the Interior, Geological Survey, Sacramento, California.

Eschmeyer, W. N. 1998. Catalog of Fishes. California Academy of Sciences, San Francisco.

Gibson, R. N. 1999. Movement and homing in intertidal fishes. M. H. Horn, K. L. M. Martin and M. A. Chatkowski, Editors. Pages 97-125 in: Intertidal Fishes: Life in Two Worlds. Academic Press, San Diego.

Griffiths, S. P. 2000. The use of clove oil as an anesthetic and method for sampling intertidal rockpool fishes. Journal of Fish Biol. 57:1453-1464.

McArdle, D. A. 1997. California marine protected areas. Publ. No. T-039, La Jolla. California SeaGrant College System.

Murray S. N., T. G. Denis, J. S. Kido, and J. R. Smith. 1999. Human visitation and the frequency and potential effects of collecting on rocky intertidal population in southern California marine reserves. CalCOFI Reports 40:100-106.

Nelson, J. S. 1994. Fishes of the world. 3rd Edition. John Wiley and Sons, Inc. New York, NY.

Nelson, J. S., E. J. Crossman, H. Espinosa-Pérez, L. T. Findley, C. R. Gilbert, R. N. Lea,

and J. D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico. American Fisheries Society, Special Publication 29, Bethesda, MD.

Parnell, P. E., C. E. Lennert-Cody, L. Geelen, L. D. Stanley, and P. K. Dayton. 2005. Effectiveness of a small marine reserve in Southern California. MEPS 296:39-52.

Pondella, Daniel J., II, and Larry G. Allen. 2000. The nearshore fish assemblage of Santa Catalina Island. D. R. Browne, K. L. Mitchell and H. W. Chaney, editors. Pages 394-400 in: The Proceedings of the Fifth California Islands Symposium. Santa Barbara Museum of Natural History, Santa Barbara, California:.

Pondella, II, D. J., L. G. Allen, M. T. Craig and B. Gintert. 2006. Evaluation of eelgrass mitigation and fishery enhancement structures in San Diego Bay, California. Bulletin of Marine Science. 78(1):155-131.

Roberts, C. 1995. Rapid build-up of fish biomass in a Caribbean marine reserve. Conservation Biology. 9(4):815-826.

Russ, G. R., and A. C. Alcala. 1996. Marine reserves: rates and patterns of recovery and decline of large predatory fish. Ecological Applications. 6(3): 947-961.

Smith, J. R., and S. N. Murray. 2005. The effects of experimental bait collection and trampling on a *Mytilus californianus* mussel bed in southern California. Marine Biology 147:699-706.

Stenack, R. S. 1998. Human influences on coastal ecosystems: Does overfishing cause trophic cascades. TREE 13(11): 429-430.

Stephens, Jr., J. S., P. A. Morris, K. E. Zerba, and M. Love. 1984. Factors affecting fish diversity on a temperate reef II: the fish assemblage of Palos Verdes Point, 1974-1981. Environmental Biology of Fishes, 11: 259-275.

Stephens, J. S., Jr., P. A. Morris, D. J. Pondella, T. A. Koonce, and G. A. Jordan. 1994. Overview of the dynamics of an urban artificial reef assemblage at King Harbor, California, USA, 1974-91: a recruitment driven system. Bulletin of Marine Science, 55 (2-3): 1224-1239.

Stephens, J. S., Jr., R. Larson, and D. J. Pondella, II. 2005. Rocky reefs and kelp beds. In press, Chapter 9 In The Ecology of Marine Fishes: California and Adjacent Waters (L. G. Allen, D. J. Pondella, II, M. Horn and, editors).

Terry, C., and J. S. Stephens, Jr. 1976. A study of the orientation of selected embiotocid fish to depth and shifting seasonal vertical temperature gradients. Bulletin of the Southern California Academy of Sciences, 75: 170-183.

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ESTIMATING RELATIVE NUMBERS OF SALT MARSH HARVEST MICE, *REITHRODONTOMYS RAVIVENTRIS*, IN TIDAL MARSHES BY TRAPPING THE HIGH MARSH ZONE

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We attempted to determine if trapping the narrow, upper band of high marsh in tidal marshes in the South San Francisco Bay gives trappers a relative idea of the number of salt marsh harvest mice, *Reithrodontomys raviventris*, in the adjacent and much deeper marsh plain, an area that very seldom can be trapped. Our results generally support our hypothesis although the value of figures obtained is likely to decrease in marshes with extremely deep marsh plains and if the trapping of the high marsh takes place during a low tide cycle. We document movement of the animals on the marsh plain up onto the high marsh levees, which helps explain these results. Trapping was carried out as part of Federal Permit TE667512-3 and a M.O.U. for the species between the California Department of Fish and Game and H. T. Harvey & Associates.

INTRODUCTION

The salt marsh harvest mice, *Reithrodontomys raviventris* (SMHM), is endemic to the salt marshes of the San Francisco Bay and is endangered primarily as a result of habitat loss (Shellhammer 1982, 2000). Its principal habitat throughout most of its range is the middle zone, or pickleweed, *Salicornia virginica*, plain of tidal salt marshes (Fisler 1965, Shellhammer 1982, Shellhammer et al. 1982). They use the upper-most zone of tidal marshes composed of halophytes such as *Frankenia salina*, *Atriplex triangularis*, and *Grindelia stricta* var. *angustifolia* as well as the middle zone composed of pickleweed. Tidal salt marshes of the San Francisco Bay formerly had much deeper middle and high marsh zones than are present today. The diking of most of the tidal marshes of the bay eliminated a large percentage of the middle zone and greatly reduced the adjoining peripheral halophyte zone. This high zone has been reduced from a band hundreds of meters deep (i.e., from grasslands to pickleweed) in pre-European times (Grossinger 2001, Collins and Grossinger 2004) to a narrow band of 1 to 2 meters deep situated along the steep outer sides of outboard dikes of salt ponds and other diked former baylands. These highest portions of the marshes of the San Francisco Bay now seldom have adjacent grasslands, hence the only high-tide escape cover remaining for the mice is either the narrow band of high marsh or gumplant growing on natural levees found along the interior channels of some of the more mature marshes, i.e., out in the marsh plain.

We have attempted over the years to estimate the density of the salt marsh harvest mice in these remaining tidal marshes. Since the numbers of these endangered animals

is typically low, it is rarely possible to use standard mark-release methods to estimate density. Therefore we typically compare populations using capture efficiency, which is a measure of relative density, i.e., the number of SMHM captured divided by the number of trap nights expended to capture them, times 100.

The other constraint is that it is not possible to trap the pickleweed-covered marsh plain except for a few exceptional low tidal cycles each year because of the threat of inundating the traps even if traps are removed each night. Therefore the only portion of tidal marshes that can be trapped during most of the year is the high marsh zone, i.e., the levee side slope. H. T. Harvey & Associates has performed over a hundred trapping studies in this zone over the last few decades, as have other consultants and university researchers, with the assumption that salt marsh harvest mice (SMHM) captured in the high marsh provide a reasonable estimate of the relative number of SMHM in the entire marsh including the marsh plain.

One of the hypotheses in this paper is that the results of such trapping adequately reflect the status of the population in the adjoining tidal marsh. This hypothesis is based on the fact that the SMHM move up onto the unsubmerged tips of the pickleweed during the highest tides (Fisler 1965) and that they also move from portions of marsh plain into what remains of the high marsh with each high tide and especially during the highest high tides. A second and related hypothesis is that trapping high marsh zones gives a sufficiently good indication of the relative numbers of SMHM on the marsh plains in narrow marshes (100 m or less) but not broader marshes (>100 m). These hypotheses had not been tested until the present study in which we trapped and marked SMHM in the high marsh and in the adjacent pickleweed plain in several marshes, compared trapping success and examined mouse movements (H. T. Harvey & Associates[1] 1990). The study was funded by the San Jose/Santa Clara Water Pollution Control Plant.

MATERIALS AND METHODS

Study Areas

The two study areas were Calaveras Point Marsh, a tidal salt marsh just east of Calaveras Point in the southern end of the South San Francisco Bay and Triangle marsh, a transitional tidal marsh made up of both saline and brackish species located 4 km southeast across Coyote Creek from Calaveras Point and 3 km north of Alviso.

Vegetation on the marsh plain of the Calaveras Point Marsh was pickleweed (Table 1) and is one of the largest remaining expanses of salt marsh in the South San Francisco Bay. The area trapped was adjacent to a salt pond and contained no major sloughs. The vegetation of the levee adjoining it consisted primarily of pickleweed with a mixture of mostly exotic plants (Table 1).

The marsh plain of Triangle Marsh consisted of a mixture of pickleweed and alkali bulrush, *Scirpus robustus*, in an approximately 2 to 1 ratio (Table 1). The marsh was

[1]H. T. Harvey & Associates. 1990. San Jose permit assistance program salt marsh harvest mouse trapping survey, Spring and Summer 1990. 55 pp.

Table 1. Vegetation characteristics in relative percent cover.

Calaveras Point Marsh	Marsh plain	Levee
Salicornia virginica	100.0	74.5
Salsola soda	0.0	13.7
Distichlis spicata	0.0	0.0
Lepidium latifolium	0.0	5.7
Atriplex triangularis, Beta vulgaris,	0.0	6.0
Total vegetation	100.0	100.0
Triangle Marsh	Marsh plain	Levee
Salicornia virginica	53.0	34.3
Scirpus robustus	24.4	0.0
Basia hyssopifolia	4.0	1.0
Grindelia stricta var. *angustifolia*	3.0	0.0
Lepidium latifolium	8.7	19.8
Frankenia salina	5.1	16.8
Atriplex triangularis	0.0	17.8
Distichlis spicata	0.9	0.0
Lepidium virginicum	0.8	10.2
Total vegetation	99.9	99.9

located next to a salt pond and contained several sloughs 3 to 4 m wide plus several smaller sloughs, all of which ran through parts of the trapping grid. Pickleweed was more common in the southeast portion of the trapping grid while alkali bulrush was more common in the northeast and southwest section of this marsh. Pickleweed and alkali bulrush were present as patches of various sizes throughout the trapping grid. The levee vegetation at Triangle was a mixture of pickleweed; peppergrass, *Lepidium latifolium*; alkali heath, *Frankenia salina*; and fat hen, *Atriplex triangularis* (Table 1).

DETERMINATION OF TIDAL ELEVATION

In order to make sure that traps placed on the marsh plains were not inundated we conducted a two-staged tidal elevation survey of the study areas. Stage 1 was an initial field reconnaissance and a staking operation in which the level of inundation of selected points in the marsh plain was observed and documented. Topographically low zones within the prospective trapping areas that were deemed questionable or potentially hazardous to trapping activities were delineated and were excluded from the second stage of the survey. Stage 2 involved a detailed level survey referenced to an established topographic benchmark, as registered by either the U.S. Geological Survey

or the U.S. Coast and Geodetic Survey. Point elevations were established along the perimeter levees and additional points were surveyed and staked along perpendicular transects that extended into the marsh plain. Surveyed point elevations along transects were chosen to encompass the full range of elevations within the prospective trapping areas.

TRAPPING

Calaveras Marsh was trapped 17–29 April 1990 with the plain trapped for first 5 nights (17-21 April 1990) and the levee trapped for the following 5 nights (25-29 April 1990). Triangle Marsh was trapped 14-25 May 1990; the levee and the plain were trapped simultaneously for the first 5 nights (14-18 May) at a low point in the tidal cycle after which the levee was trapped for 5 more nights (21-25 May) when high tides covered the marsh plain during both day and night. The grids were 100 traps set in a 4 by 25 pattern and trapped for 5 consecutive nights, for a total of 500 trap nights. Levee transect lines were composed of 100 traps placed at 5-m intervals with the line's center point being opposite the middle of the grid on the adjacent marsh; they were also trapped for 5 nights or 500 trap nights

We used 7.62 x 7.62 x 25.4 cm non-folding Sherman live-traps baited with a mixture of rolled oats, walnuts, and birdseed. As required by the Federal Endangered Species trapping permit held by the junior author, we provisioned each trap with nesting material and covered the outside of each trap with vegetation to reduce solar heating and nocturnal heat loss. Levee traps were checked each morning and then closed during the day and opened each evening. In the tidal plains, we removed the traps each day after checking them to avoid inundation during daytime high tides.

All captured small mammals species were identified, uniquely marked using numbered ear tags, weighed, and sexed. Salt marsh harvest mice were identified using tail traits developed by Fisler (1965) and quantified by Shellhammer (1984).

RESULTS

Fifty-nine salt marsh harvest mice were captured on the marsh plain of the Calaveras Point Marsh, 45 were captured on the levee and 9 individuals were captured in both areas. A smaller number of SMHM were captured in Triangle Marsh, where 14 were captured on marsh plain, 4 were captured on the levee during the same week the plain was trapped and 17 were captured a week later, when only the levee was trapped. Six animals were captured on both the marsh plain and the levee at Triangle Marsh. The difference between the numbers of animals captured in the marsh plain and on the levee at Calaveras was not significant ($\chi^2 = 1.71$, df= 1, $P = 0.2$). The difference between SMHM captured on the plain and levee at Triangle was significant for the simultaneous trapping ($\chi^2 = 5.46$, df= 1, $P < 0.02$) but the results of the second week of trapping on the levee was not significant when compared to the prior trapping of the plain ($\chi^2 = 0.02$, df= 1, $P = 0.6$). The number of SMHM captured on the levee during the first and second week of trapping at Triangle was significantly different ($\chi^2 = 7.88$, df= 1, $P < 0.01$).

The average distance moved between captures for the 9 animals at Calaveras Point that moved from the plain to the levee was 40 m (20-100 m), for the 6 SMHM in Triangle it was 64 m (22-111 m). More animals moved to the levee from the two rows of traps nearest the levee than from the two rows further away in both marshes and only one in each marsh moved from the most distant line to the levee, a straight-line distance of approximately 45 to 50 m.

Table 2. Small mammals captured.

Site	TN[1]	SMHM	Voles[2]	House[3] mice	Deer[4] mice
Calaveras Point					
Marsh plain	500	59	7	0	0
Levee	500	45	86	6	0
Triangle Marsh					
Marsh plain	500	14	40	0	0
Levee					
Week 1	500	4	6	1	2
Week 2	500	17	46	4	4

[1]TN = trap nights, [2] *Microtus californicus*, [3] *Mus musculus*, [4]*Peromyscus maniculatus*

DISCUSSION

In both Calaveras and Triangle marshes, no significant differences were observed between the numbers of SMHM captured in the marsh plain at low tide and on the levees at high tide in two of the three trapping situations. This suggests that trapping results from higher portions of marshes can be representative indicators of the density of SMHM in the entire marsh. However, other results from our study suggest that this relationship may be true only under certain, albeit common conditions. The number of SMHM captured on the levee at Triangle Marsh during the lower of the two low tide cycles was significantly lower than during a higher low tide cycle. This suggests to us that the mice move up onto the high portions of the marsh during higher tide cycles and hence the correspondence between SMHM capture rates on the marsh plains and the levees may be more valid during higher tide cycles. Furthermore, data for the individual SMHM captured on both the marsh plain and the levees in the two marshes suggest that individual mice are most likely to move to the levees when their home range is within 100 m of the levee. This conclusion is supported by the data from Geissel at al. (1988), in one of the few studies that documented home range sizes in the South San Francisco Bay, that indicated that home ranges were 1300 to 1500 m^2 for adults and that

average distances moved between captures were 20.3 m for adult females and 30.8 m for adult males with long-distance movements of as much as 85 m by males.

Home ranges can be configured in various ways but if we consider them to be more or less square then the adult male mice in the study of Geissel et al. (1988) lived in approximately 39 x 39 m home ranges. Based on the data from that study the animals moving from the plain to the levee at Calaveras Point were moving a home range width and some of the animals in the Triangle Marsh were moving more in the range of long distance moves. In any case it does not appear to us based on these brief studies that animals who live more than two home ranges, i.e., 80 to 90 m into the marsh plain are likely to move up to the high marsh levees in response to high tides but rather move up into the highest stems of pickleweed, or Grindelia, on the marsh plain. This hypothesis is partially supported by the fact that 25.5% of the SMHM captured at Triangle Marsh were captured in both the plain and levee while only 8.6% were so captured at Calaveras Point, a much deeper marsh than Triangle.

The evidence suggests that trapping the high marsh does give a relatively good idea of the SMHM living in the first 100 m towards the bay from the high marsh. The value of that figure is likely to decrease by some presently unknown degree in deeper marshes (i.e., with marsh plains much more than 100 m deep) and if the high marshes are trapped during low tidal cycles. Since many of the marshes lining the South San Francisco Bay are 100 m or less in depth this analysis suggests we can use trapping results from high marshes to compare most of the narrower marshes as to their relative number of salt marsh harvest mice based upon capture efficiency data. We also suggest that using this method will tend to give an under-estimate when trapping is done along side of much deeper (i.e., much more than 100 m) marshes.

LITERATURE CITED

Collins, J. N. and R. M. Grossinger. 2004. Synthesis of scientific knowledge concerning estuarine landscapes and related habitats of the South Bay Ecosystem. Technical Report of the South Bay Salt Pond Restoration Project, San Francisco Bay Estuary Institute, Oakland, CA. 92pp.

Fisler, G. F. 1965. Adaptations and speciation in harvest mice of the marshes of the San Francisco Bay. University of California Publications in Zoology 77:1-108.

Geissel, W, H. Shellhammer and H. T. Harvey. 1988. The ecology of the Salt-marsh harvest mouse (*Reithrodontomys raviventris*) in a diked salt marsh. Journal of Mammalogy 69:696-703.

Grossinger, R. M. 2001. Documenting local landscape change: The Bay Area Historical Ecology Project. *In* The Historical Ecology Handbook: A Restorationist's Guide to Reference Ecosystems (D. Egan and E. Howell, eds.). Island Press, Washington, D.C.

Shellhammer, H. S. 1982. *Reithrodontomys raviventris*. Mammalian Species, No. 169:1-3. The American Society of Mammalogists.

Shellhammer, H. S. 1984. Identification of salt marsh harvest mice, *Reithrodontomys raviventris*, in the field and with cranial characteristics. California Fish and Game, 70(2):75-80.

Shellhammer, H. S. 2000. Salt marsh harvest mouse. Pp. 219-228 *in* Goals Project 2000. Baylands ecosystem species and community profiles; Life histories and environmental requirement of key plants, fish and wildlife. Prepared by the San Francisco Bay Area

Wetlands Ecosystem Project. P. R. Olofson, editor. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.
Shellhammer, H. S., R. Jackson, W. Davilla, A. M. Gilroy, H. T. Harvey and L. Simons. 1982. Habitat preferences of salt marsh harvest mice (*Reithrodontomys raviventris*). Wasmann Journal of Biology 40(1-2):102-114.

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POTENTIAL PREY RESOURCES FOR MARBLED MURRELETS IN CENTRAL CALIFORNIA

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ABSTRACT

Information on the diet of the Marbled Murrelet, *Brachyramphus marmoratus*, in California is lacking. To assess availability of potential prey, we sampled small fishes at three locations in central California: Año Nuevo Bay, and two sites in northern Monterey Bay. These sites are used seasonally by Marbled Murrelets. Nearshore marine habitats were sampled with a midwater trawl during 2000, 2001, and 2002. We caught 36 taxa of demersal and midwater fish and cephalopods. Numerically dominant species at all sites were northern anchovy, *Engraulis mordax*, night smelt, *Spirinchus starski*, and white croaker, *Genyonomus lineatus*. The occurrence of these fishes concurrent with Marbled Murrelets provides information on potential prey available to Marbled Murrelets in central California.

INTRODUCTION

The Marbled Murrelet, *Brachyramphus marmoratus*, is a small, threatened seabird that nests in coastal coniferous forests from Alaska south to central California. The southernmost population, of approximately 600 birds breeding in the Santa Cruz Mountains, is at risk of extinction (McShane et al. 2004[2], Peery et al. 2004). Very little is known regarding the diet of Marbled Murrelets in central California yet information on prey ecology is important in determining appropriate conservation measures.

Diet of Marbled Murrelets is difficult to study. Their secretive nesting habits make observation of prey deliveries to chicks difficult and, throughout most of the species' range, low population levels preclude collection of individuals for stomach content analysis. Diet has been fairly well studied in Alaska and elsewhere north of California where Marbled Murrelets are most abundant. There, Marbled Murrelets forage primarily on Pacific herring, *Clupea pallasi*, smelts (Osmeridae), sand lance, *Ammodytes*

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[2]McShane, C., T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation report for the 5-year status review for the Marbled Murrelet in Washington, Oregon, and California. Prepared for the U.S. Fish and Wildlife Service, Region 1. Portland, OR.

hexapterus, and pelagic crustaceans (Euphausiidae and Mysidae; Burkett 1995). In California, information on diet is scarce. Only two studies of stomach contents have been conducted in California. Beck (1910) collected 19 Marbled Murrelets in Monterey Bay during the non-breeding season nearly a century ago, and found Pacific sardine, *Sardinops sagax*, and possibly sand lance (Burkett 1995). Paul Kelly (pers. comm. cited in Carter and Erikson 1988[3]) collected 10 Marbled Murrelets in Monterey Bay, during the non-breeding season in the late 1970s. He found primarily northern anchovy, *Engraulis mordax*, and to a lesser extent, a slim fish he tentatively identified as California needlefish, *Strongylura exilis*. California needlefish are rarely recorded in the Monterey Bay area (they are more common south of Point Conception), and Carter and Erickson (1988[4]) theorized that the supposed needlefish were sand lance. Additional opportunistic sightings of murrelets holding fish indicate that northern anchovy are taken in California (Burkett 1995).

Becker and Beissinger (2003) attempted to sample prey located using sonar near foraging Marbled Murrelets during the summers of 1999 and 2000, at Año Nuevo Bay, in central California. Using herring jigs, they caught Pacific herring, Pacific sardine, northern anchovy, juvenile rockfish, *Sebastes* spp., and sanddabs, *Citharichthys* spp. Becker (2001) also used stable isotopes to assess Marbled Murrelet trophic level in central California. Analysis of feather samples indicated the trophic level at which the birds were feeding when the feathers were grown during pre-alternate (spring) and pre-basic (fall) molt. During 1999 and 2000, he found that, before pre-alternate molt in spring, Marbled Murrelets fed at a lower trophic level (presumably on euphausiids or mysids) than before pre-basic molt in fall.

To better understand what prey resources are available to Marbled Murrelets in central California, we sampled nearshore waters where Marbled Murrelets occur seasonally. Off California, Marbled Murrelets forage primarily within 2 km of shore, usually in waters < 20 m deep (Nelson 1997). They feed almost exclusively diurnally (Nelson 1997, Henkel et al. 2003, E. Burkett unpubl. data, Z. Peery unpubl. data), and presumably feed throughout the water column. We sampled this habitat at three sites in central California. Although Marbled Murrelets may select prey based on energetic value (Ostrand et al. 2004), to some extent, diet reflects availability of prey (Burkett 1995). Forage fish in central California may not be taken in proportion to their availability, but determining which species are available is an important step in theorizing about the diet of Marbled Murrelets at the southern edge of their range.

METHODS

Study Area

The primary study area consisted of the nearshore waters of Año Nuevo Bay, on the central California coast (Fig. 1), to approximately 1.5 km offshore. The bottom is

[3]Carter, H.R., and R.A. Erickson. 1988. Population status and conservation problems of the Marbled Murrelet in California, 1892-1987. Unpublished Report, California Department of Fish and Game, Sacramento, CA.

[4]Op.Cit.

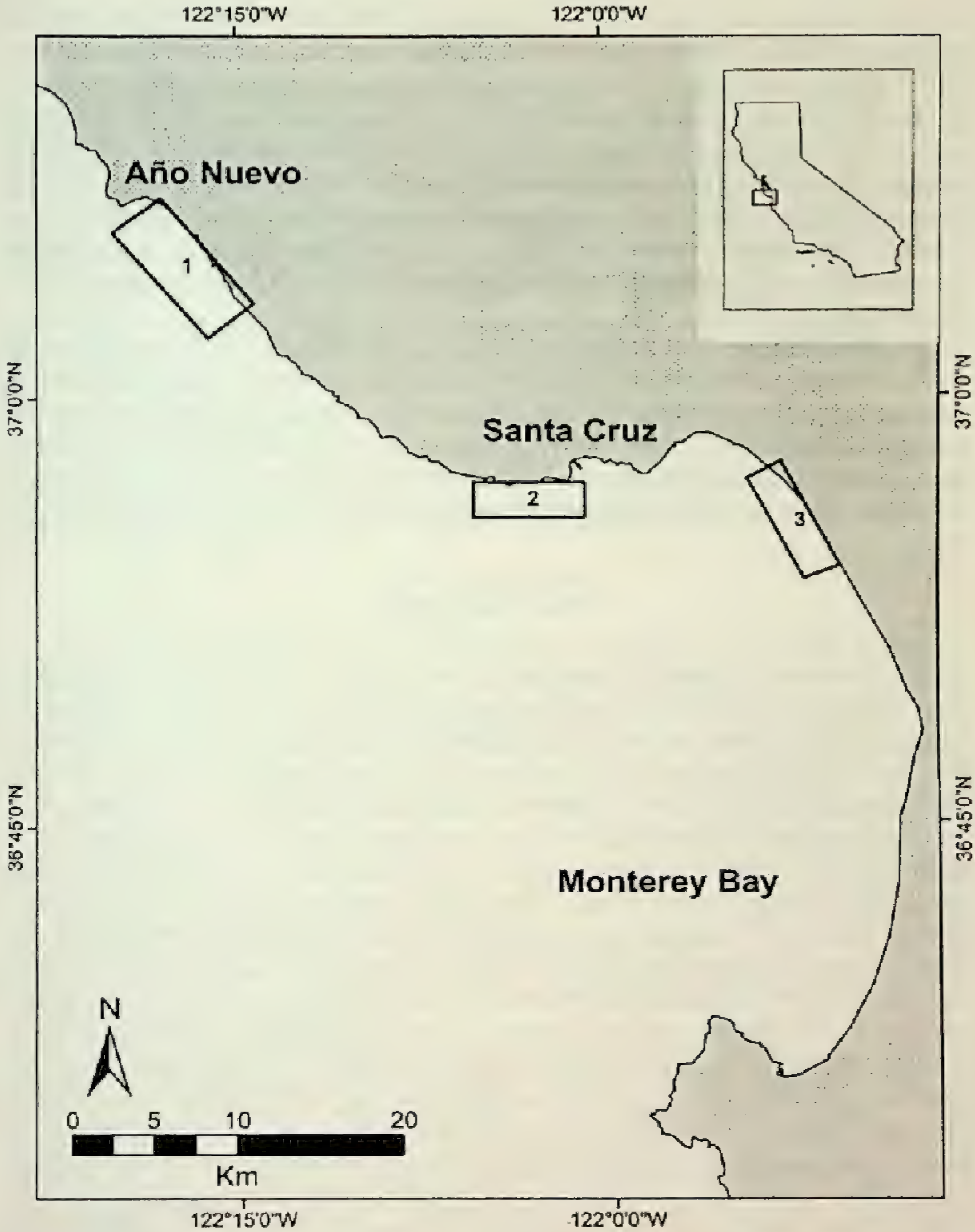

Figure 1. Approximate sampling locations at Año Nuevo (1), Terrace Point (2), and Monterey Bay (3), in central California.

primarily sandy, with occasional rocky outcrops. Old-growth forest habitat located directly inland from Año Nuevo Bay in the Santa Cruz Mountains (Santa Cruz and San Mateo counties) is one of three primary nesting locales of Marbled Murrelets in California, and represents the southern extent of their known breeding range (Carter and Erickson 1988[5]). This area is known regionally for concentrations of Marbled Murrelets throughout the breeding season (April through September; Becker and Beissinger 2003). The depth within the study area is mostly < 25 m. Waddell Creek, a perennial freshwater stream, flows into Año Nuevo Bay, and beds of giant kelp, *Macrocystis pyrifera*, and smaller beds of bull kelp, *Nereocystis luetkeana*, grow within the bay.

Additional sampling was conducted at two sites south of Año Nuevo Bay with seasonal concentrations of Marbled Murrelets (Fig. 1). Nearshore waters off Terrace Point, in Santa Cruz, are characterized by substantial beds of giant kelp, and a rocky shoreline. Nearshore waters of Monterey Bay, off Aptos, are underlain with a uniform sandy bottom and shoreline. Marbled Murrelets are sometimes abundant off Terrace Point during summer and fall, and in Monterey Bay during winter (LAH and JTH unpubl. data).

Prey Sampling

We sampled Año Nuevo Bay four times (4 April 2000, 9 November 2001, 6 December 2001, and 19 July 2002). Terrace Point was sampled once (9 November 2001), and Monterey Bay was sampled once (6 December 2001). Sampling dates in Año Nuevo Bay were intended to cover all seasons, and dates at the other two sites roughly correspond to the time of year when many Marbled Murrelets use those areas. We sampled prey from the 18-m R/V John Martin, using an Otter Trawl used as a midwater sampler, with an opening of approximately 5 m x 2 m, length of 4.5 m, mesh size of 30 mm, and cod end mesh size of 20 mm. We made between 4 and 9 tows each day, varying in length from 6 to 43 minutes. Sampling effort (total fishing time) ranged from 100 to 139 minutes on the 4 sampling days at Año Nuevo Bay (100, 115, 139, and 120 minutes respectively). Sampling effort at Terrace Point was 26 minutes; at Monterey Bay it was 30 minutes. We fished in sinuous patterns, sampling all depths between the surface and the bottom, which was typically about 10 m depth. We maintained a speed of between 7 and 9 km per hr on each trawl. Tows were conducted in daylight, between 0900 and 1400h. Fish were identified using Miller and Lea (1972) to lowest possible taxon, and standard length (mantle length for squid) was measured to $\pm$ 1 mm. During April 2000, we conducted several experimental trawls in Año Nuevo Bay using a Tucker Trawl with an opening of 1.6 m x 1.8 m, length of 14 m, and 10 mm stretch diagonal mesh size tapering to 6.5 mm. This proved unsatisfactory in capturing forage fish, and the net became clogged with large quantities (up to 10 liters per trawl) of porcelain crab, *Petrolisthes* sp., zoeae.

[5]Op.Cit.

RESULTS

We caught 36 taxa of demersal and mid-water fish and cephalopods (Table 1), 34 taxa in Año Nuevo Bay, 5 taxa off Santa Cruz, and 10 taxa in Monterey Bay. The most abundant fish and cephalopod species were northern anchovy, night smelt, *Spirinchus starski*, white croaker, *Genyonomus lineatus*, and market squid, *Loligo opalescens*. Most fish were between 30 mm and 100 mm in length (Table 2), an appropriate size for Marbled Murrelet prey (Nelson 1997).

The number of new taxa caught during each sampling day was high (Table 1). No taxon was caught consistently during each sampling day, and only night smelt and white croaker were caught in three out of four sampling days at Año Nuevo. Night smelt and northern anchovy were the only species caught at all three locations.

Crustaceans (e.g., mysids) were not the focus of this study, and are not included in Table 1 or 2. Crustaceans incidentally caught at Año Nuevo Bay included numerous spot prawns, *Pandalus platyceros*, several coon shrimp, *Pandalus danae*, one hyperiid amphipod, *Hyperia medusarum*, and unidentified mysids.

DISCUSSION

The majority of individual species were caught on only one sampling day, indicating that species composition in Año Nuevo Bay may change throughout the year, or that the diversity of small fish present was not sampled at a level adequate to fully describe the fish communities at these sites. However, our goal was to assess which potential prey species were most abundant in the study area; uncommon species occurring only once are likely of little importance to Marbled Murrelet diet. Our data provide the first assessment of possible prey species in Año Nuevo Bay at different times of the year. In this respect, sampling was adequate to assess which prey species might be used by Marbled Murrelets in this important area, and to some extent, how these prey resources might change through time. However, sampling of small schooling fish involves high variability, and prey resources may change on time scales ranging from days to decades along the central California coast.

Seasonal changes in CPUE at Año Nuevo Bay may not reflect actual forage fish abundance, but they did correspond roughly to observed abundance of piscivorous birds inthe study area (LAH and JTH, unpubl. data). Our catch was less in December than during other sampling days, and greater in November, with intermediate catches in April and July (Table 2). These data indicate that prey abundance may be greatest in Año Nuevo Bay during fall, with night smelt, northern anchovy, and white croaker most abundant. If the lesser CPUE during July represented lesser forage fish abundance, then Marbled Murrelets may be energetically challenged during late summer, when they are rearing chicks. Marbled Murrelets are likely limited in their foraging range during summer, when they nest inland from Año Nuevo Bay, but are free to move post-breeding to areas of greater prey abundance. In winter, prey abundance may decrease at Año Nuevo Bay, perhaps due to severe weather on this exposed outer coast. During this time, many Marbled Murrelets apparently move from

Table 1. Catch per unit effort (CPUE) of fishes and squid at three locations in central California. CPUE is number of fish (shown in parentheses) caught per hour.

		Año Nuevo Bay				Terrace Point	Monterey Bay
Common name	Scientific name	4/4/00	11/9/01	12/6/01	7/19/02	11/9/01	12/6/01
White croaker	*Genyonemus lineatus*	1.8 (3)	32.8 (76)		8.9 (17)		532.0 (266)
Northern anchovy	*Engraulis mordax*	1.2 (2)	98.8 (229)			142.6 (62)	210.0 (105)
Night smelt	*Spirinchus starski*	16.8 (28)	77.3 (179)		16.2 (31)	23.0 (10)	*
Market squid	*Loligo opalescens*	0.6 (1)	14.2 (33)				*
Bay pipefish	*Syngnathus leptorhynchus*		1.7 (4)		0.5 (1)		14.0 (7)
English sole	*Parophrys vetulus*	0.6 (1)					6.0 (3)
Black rockfish	*Sebastes melanops*				4.2 (8)	2.3 (1)	
Speckled sanddab	*Citharichthys stigmaeus*		0.4 (1)		4.7 (9)		
Greenling species	*Hexagrammos* sp.		1.3 (3)		3.7 (7)		
Pacific sanddab	*Citharichthys sordidus*	4.2 (7)					
Pacific tomcod	*Microgadus proximus*						4.0 (2)
Tubesnout	*Aulorhynchus flavidus*				1.6 (3)		2.0 (1)
Sculpin sp. (Icelinus)	*Icelinus* sp.		2.6 (6)		1.0 (2)		
Pricklebreast poacher	*Stellerina xyosterna*	3.0 (5)					
Blue rockfish	*Sebastes mystinus*		0.4 (1)			2.3 (1)	
Yellowtail rockfish	*Sebastes flavidus*				0.5 (1)		2.0 (1)
White seaperch	*Phanerodon furcatus*					2.3 (1)	
Copper rockfish	*Sebastes caurinus*				2.1 (4)		
Pacific sardine	*Sardinops sagax*						2.0 (1)
Cabezon	*Scorpaenichthys marmoratus*		0.4 (1)		1.6 (3)		
Spotfin surfperch	*Hyperprosopon anale*	1.8 (3)					
Rockfish species	*Sebastes* spp.	1.8 (3)					
Plainfin midshipman	*Porichthys notatus*	0.6 (1)	0.4 (1)				
Shortbelly rockfish	*Sebastes jordani*				1.0 (2)		
Smoothhead sculpin	*Artedius lateralis*			0.6 (1)			
Boneyhead sculpin	*Artedius notospilotus*	0.6 (1)					

Table 1 (continued)

Common name	Scientific name	Año Nuevo Bay 4/4/00	11/9/01	12/6/01	7/19/02	Santa Cruz 11/9/01	Monterey Bay 12/6/01
Walleye surfperch	*Hyperprosopon argenteum*			0.6 (1)			
Pygmy poacher	*Odontopyxis trispinosa*	0.6 (1)					
Sand sole	*Psettichthys melanostictus*	0.6 (1)					
Queenfish	*Seriphus polius*	0.6 (1)					
Stripefin ronquil	*Rathbunella alleni*				0.5 (1)		
Kelp perch	*Brachyistius frenatus*				0.5 (1)		
Striped kelpfish	*Gibbonsia metzi*				0.5 (1)		
Brown Irish lord	*Hemilepidotus spinosus*				0.5 (1)		
Gopher rockfish	*Sebastes carnatus*		0.4 (1)				
Pacific herring	*Clupea pallasi*		0.4 (1)				

* Species recorded, but data lost.

Table 2. Mean length (mm; SD in parentheses) of fish and squid caught at three locations in central California.

		Año Nuevo Bay				Santa Cruz	Monterey Bay
Common name	Scientific name	4/4/00	11/9/01	12/6/01	7/19/02	11/9/01	12/6/01
White croaker	*Genyonemus lineatus*	200.0 (37.8)	48.5 (13.9)		30.9 (3.8)		71.9 (17.7)
Northern anchovy	*Engraulis mordax*	102.5 (3.5)	44.5 (11.1)			58.0 (10.3)	69.9 (8.4)
Night smelt	*Spirinchus starski*	69.6 (15.0)	53.1 (25.0)		37.4 (10.4)	78.5 (15.9)	*
Market squid	*Loligo opalescens*	18.0 (0)	26.3 (8.8)				*
Bay pipefish	*Syngnathus leptorhynchus*		159.3 (26.9)		155.0 (0)		156.1 (22.2)
English sole	*Parophrys vetulus*	162.0 (0)					129.7 (36.2)
Black rockfish	*Sebastes melanops*				46.1 (4.9)	300.0 (0)	
Speckled sanddab	*Citharichthys stigmaeus*		45.0 (0)		55.2 (16.7)		
Greenling species	*Hexagrammos* sp.		115.7 (12.9)		87.1 (33.3)		
Pacific sanddab	*Citharichthys sordidus*	78.9 (14.6)					
Pacific tomcod	*Microgadus proximus*						109.0 (0)
Tubesnout	*Aulorhynchus flavidus*				142.3 (5.0)		130.0 (0)
Sculpin sp. (Icelinus)	*Icelinus* sp.		73.3 (39.3)		33.0 (2.8)		
Pricklebreast poacher	*Stellerina xyosterna*	75.8 (18.3)					
Blue rockfish	*Sebastes mystinus*		91.0 (0)			80.0 (0)	
Yellowtail rockfish	*Sebastes flavidus*				43.0 (0)		62.0 (0)
White seaperch	*Phanerodon furcatus*					115.0 (0)	
Copper rockfish	*Sebastes caurinus*				39.8 (1.0)		
Pacific sardine	*Sardinops sagax*						82.8 (7.8)
Cabezon	*Scorpaenichthys marmoratus*		205.0 (0)		65.7 (21.1)		
Spotfin surfperch	*Hyperprosopon anale*	87.0 (0)					
Rockfish species	*Sebastes* spp.	28.7 (0)					
Plainfin midshipman	*Porichthys notatus*	62.0 (0)	51.0 (0)				
Shortbelly rockfish	*Sebastes jordani*				29.0 (4.2)		
Smoothhead sculpin	*Artedius lateralis*			60.0 (0)			
Boneyhead sculpin	*Artedius notospilotus*	127.0 (0)					

Table 2 (continued)

		Año Nuevo Bay				Santa Cruz	Monterey Bay
Common name	Scientific name	4/4/00	11/9/01	12/6/01	7/19/02	11/9/01	12/6/01
Walleye surfperch	*Hyperprosopon argenteum*			92.0 (0)			
Pygmy poacher	*Odontopyxis trispinosa*	76.0 (0)					
Sand sole	*Psettichthys melanostictus*	106.0 (0)					
Queenfish	*Seriphus polius*	166.0 (0)					
Stripefin ronquil	*Rathbunella alleni*				70.0 (0)		
Kelp perch	*Brachyistius frenatus*				92.0 (0)		
Striped kelpfish	*Gibbonsia metzi*				76.0 (0)		
Brown Irish lord	*Hemilepidotus spinosus*				49.0 (0)		
Gopher rockfish	*Sebastes carnatus*		209.0 (0)				
Pacific herring	*Clupea pallasi*		52.0 (0)				

* Species recorded, but data lost.

the Año Nuevo Bay area south to Monterey Bay (Henkel 2004). Studies elsewhere indicated Marbled Murrelets fed more extensively on crustaceans (euphausiids and mysids) during winter, presumably in response to a decreased availability of fish (Burkett 1995). In spring and summer, prey abundance in Año Nuevo Bay may be at an intermediate level, comprised primarily of night smelt, and in summer, juvenile rockfish.

We caught all prey species previously considered prey of Marbled Murrelets in California, with the exception of sand lance. Sand lance are an important prey species for Marbled Murrelets north of California (Burkett 1995), but they become increasingly scarce with decreasing latitude. Sand lance is not a common prey for other seabirds in central California (Morejohn et al. 1978), but it has been documented in the area (Kukowski 1972[6], Hester 1998[7]). It is interesting that in two historic diet studies in Monterey Bay (Beck 1910, P. Kelly, pers. comm. in Carter and Erickson 1988[8]), sand lance apparently occurred in Marbled Murrelet stomachs. No data are available regarding changes in sand lance populations in California, but the range of this northern species may have retracted concurrent with a warming trend in the California current between 1977 and 1999 (Chavez et al. 2003). It is also possible that our sampling method was ineffective at capturing sand lance, but the low occurrence of this species in the diets of other local seabird species indicates that it is not likely abundant in central California.

In Monterey Bay, forage fish abundance has been fairly well studied (Morejohn et al. 1978, Byrd 2001[9]). Prey species that we caught in Monterey Bay correspond to those reported in other studies. Northern anchovy and market squid are generally the species found most often in the diet of marine birds and mammals in Monterey Bay (Morejohn et al. 1978); unfortunately our data on these species in Monterey Bay were lost, although both were abundant in Monterey Bay trawls. It is interesting that both our study and Byrd's (2001[10]) found white croaker to be abundant in nearshore waters. This species has not been widely reported in the diet of birds, but has been reported in the diet of harbor seal, *Phoca vitulina* (Harvey et al. 1995, Oxman 1995[11]). This may reflect a bias of avian diet studies being located farther offshore, or it could be that something about white croaker (perhaps their greater cross-sectional area compared with other small fishes) makes them difficult for birds to ingest. Alternatively, white croaker may

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[6]Kukowski, G. 1972. A checklist of the fishes of the Monterey Bay area including Elkhorn Slough, the San Lorenzo, Pajaro and Salinas Rivers. Unpublished Report. Moss Landing Marine Laboratories Technical Report 72-02, Moss Landing, CA.

[7]Hester, M.M. 1998. Abundance, reproduction, and prey of Rhinoceros Auklet (*Cerorhinca monocerata*) on Año Nuevo Island, California. M.S. Thesis, San Francisco State University.

[8]Op.Cit.

[9]Byrd, B.L. 2001. Abundance, distribution, food habits, and prey availability of the harbor porpoise (*Phocoena phocoena*) in northern Monterey Bay, California. M.S. Thesis, California State University, Stanislaus.

[10]Op.Cit.

[11]Oxman, D.S. 1995. Seasonal abundance, movements, and food habits of harbor seals (*Phoca vitulina richardsi*) in Elkhorn Slough, California. M.S. Thesis, California State University, Stanislaus.

have poor energetic value, and birds may choose other, potentially less abundant, more profitable prey over croaker.

Ostrand et al. (2004) found that Marbled Murrelets in Prince William Sound, Alaska, preferentially foraged on energy-rich Pacific herring, even when energy-poor Gadids (e.g., walleye Pollock, *Theragra chalcogramma*) were more abundant. Among potential prey species in central California, published energetic values for northern anchovies (20.6 to 26.7 kJ/g dry mass) and market squid (20.7 to 20.9 kJ/g) are high, and night smelt (19.8 kJ/g) and surf smelt, *Hypomesus pretiosus* (18.8 kJ/g), closely related to night smelt, are also energetically rich (Spear 1993, Van Pelt et al. 1997, Anthony et al. 2000, Dahdol and Horn 2003). Pacific herring and various flatfish are slightly lower in energy density (16.5 to 17.8 kJ/g; Spear 1993, Anthony et al. 2000). Rockfish appear to be more variable in energy density (likely depending on location, season, and species): Spear (1993) reported energetic density of 21.8 kJ/g dry mass for shortbelly rockfish, *Sebastes jordani*, in central California, but Van Pelt et al. (1997) reported a value of 15.9 kJ/g for unidentified rockfish species from the Gulf of Alaska. Energetic values for white croaker are not available. Differences in prey quality mean that of the more abundant prey species we caught, not all are necessarily taken by Marbled Murrelets. We suspect that in central California, primary prey species for Marbled Murrelets include night smelt, northern anchovy, and juvenile rockfish.

Ecology of Potential Prey

Night Smelt

Night smelt have not been reported as a prey species of Marbled Murrelets, but other osmerid fish are important prey for murrelets (Burkett 1995), and we propose that night smelt are likely an important prey for Marbled Murrelets in central California. Night smelt are common prey of Common Murre, *Uria aalge*, in central California (Ainley and Boekelheide 1990, Croll 1990[12]), yet little is known about the ecology of night smelt. Night smelt spawn on beaches at night, typically on high tides after the full moon (Fitch and Lavenberg 1971). Scott Creek, just south of the Año Nuevo study area, is a reported spawning location for night smelt (Fitch and Lavenberg 1971), but central California has not been surveyed for other spawning locations. Night smelt in northern California spawn in substrates ranging in grain size from <1 mm to 6 mm, but are most abundant in grain sizes <1 mm (Slama 1994[13]). Ideal spawning conditions for the species are in habitats 1.2 m to 1.6 m in depth, at dusk during falling tides (Slama 1994[14]).

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[12]Croll, D.A. 1990. Physical and biological determinants of the abundance, distribution, and diet of the Common Murre (*Uria aalge*) in Monterey Bay, California. Ph.D. dissertation, Scripps Institution of Oceanography, U.C. San Diego.

[13]Slama, D.J. 1994. The biology of the night smelt (*Spirinhus starski*) off northern California. M.S. thesis, Humboldt State University, Arcata, CA.

[14]Op.Cit.

Night smelt apparently spawn from March to October (peaking in July), but Slama (1994[15]) found that abundance and length distribution of night smelt off a northern California beach did not change significantly by season. We found that length distribution of night smelt in Año Nuevo Bay did vary by season (Fig. 2). Larval and small juvenile fish were present in July and November, but not in April or December. These data are consistent with local spawning beginning after April, and continuing at least through October. We propose that night smelt are an important prey species for Marbled Murrelets in central California, and more research on the local distribution and spawning habits of this little-studied species would be beneficial for educated management considerations for Marbled Murrelets.

Northern Anchovy

Northern anchovy is an abundant schooling fish in California waters year-round (Cailliet et al. 1979). During late summer and fall, large, dense schools often can be found close to shore. The anchovies caught in this study, with mean lengths less than 100 mm, were first-year fish, which are typically found nearshore (Parrish et al. 1985). Adult anchovies (age 2+) move offshore to spawn during winter. Anchovy are an important prey species for many seabirds in California, including Marbled Murrelets (Morejohn et al. 1978, Burkett 1995). Anchovy are a high-calorie prey, and may be important for Marbled Murrelet nestlings, which are fed only one fish per adult visit to the nest (Becker2001).

Juvenile Rockfish

Rockfish in California give birth to young primarily from January to March, and peak settlement of juveniles (10 to 30 mm) to nearshore habitats occurs from May to July (Love et al. 1991, Leet et al. 2001[16]). Juvenile rockfish form schools in a variety of habitats, and many species are typically found near kelp beds (Bodkin 1986). Marbled Murrelets prey on juvenile rockfish, and rockfish are important prey for many other seabirds in California (Ainley and Boekelheide 1990, Croll 1990[17], Ainley et al. 1993, Burkett 1995). Abundance of juvenile rockfish during summer is related to upwelling conditions during spring. During years when upwelling in late spring is pulsed or relaxed, juvenile rockfish are not advected offshore and are more abundant nearshore (Ainley et al. 1993).

Other Species

White croaker have not been reported in the diet of Marbled Murrelets (Burkett 1995), but the individuals captured in this study were in the size range suitable for

[15]Op.Cit.

[16]Leet, W.S, C.M. Dewees, R. Klingbeil, and E.J. Larson (eds.). 2001. California's living marine resources: a status report. Sacramento: California Dept. Fish and Game, Sacramento.

[17]Op.Cit.

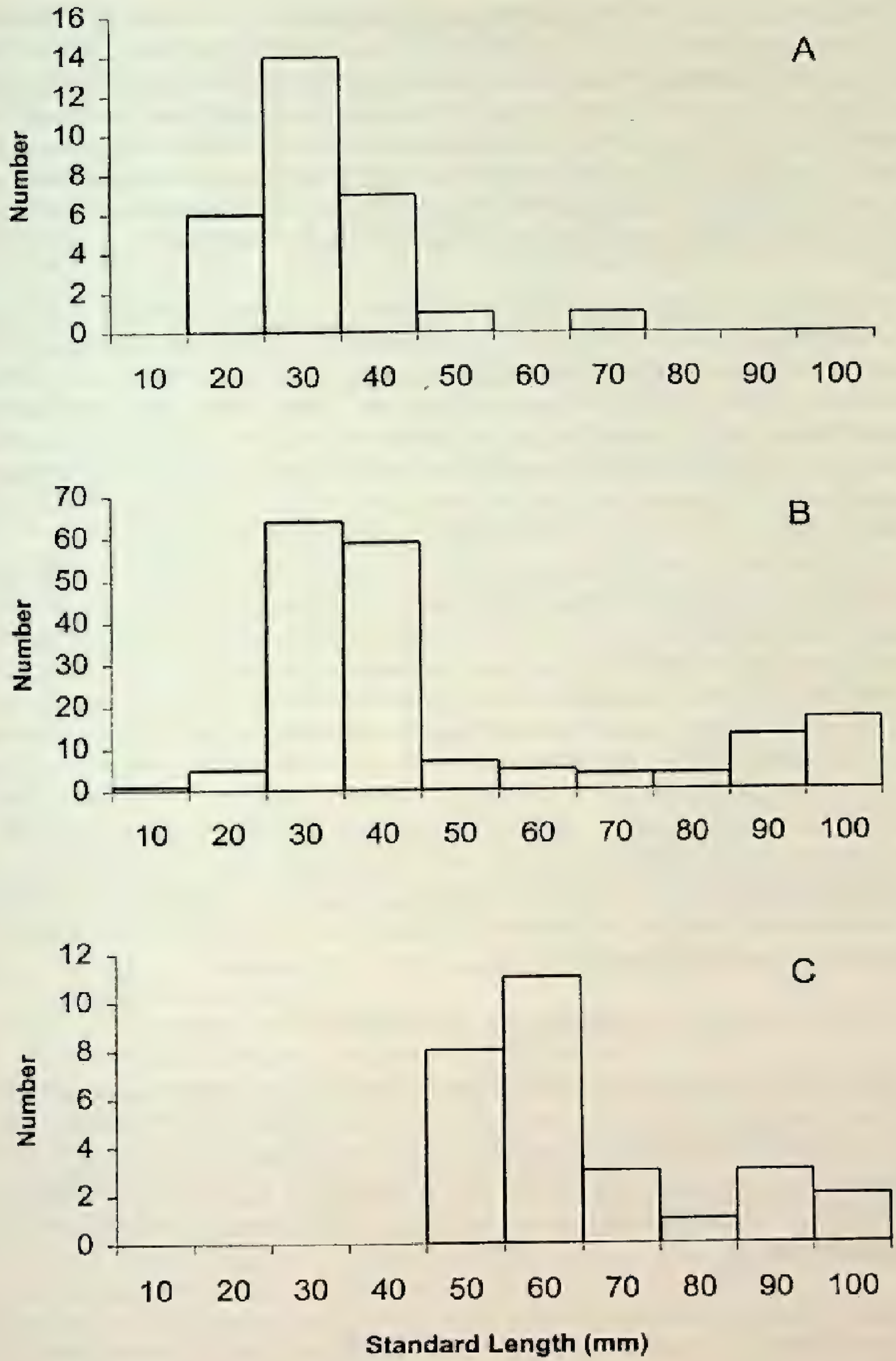

Figure 2. Frequency distributions of standard length of night smelt caught in July 2002 (A), November 2001 (B), and April 2000 (C) in central California.

Marbled Murrelet prey. White croaker are common nearshore fish in central California, where they occur primarily off sandy beaches. Croaker spawn year-round offshore in the pelagic environment, and juveniles then migrate inshore (Leet et al. 2001[18]). The consistent presence of croaker among our samples indicates that this species is available to murrelets in the study area. It is not known whether Marbled Murrelets prey on white croaker, or choose less abundant prey that may be more palatable or energetically dense. Information on the energy density of white croaker would be useful in determining why this abundant small fish is not taken more often by marine birds.

Market squid is a prey item of Marbled Murrelets, and an important prey for many other seabird species (Morejohn et al. 1978, Burkett 1995). Squid spawn in the pelagic environment from April to November (Leet et al. 2001[19]). Sanddabs have not been reported in the diet of Marbled Murrelets (Burkett 1995), but sanddabs in this study were in the size range suitable for prey. Sandabs are common over sandy or muddy substrates, and spawn pelagically in summer months (Leet et al. 2001[20]). Although zooplankton have been reported as important prey of Marbled Murrelets in some locations (Burkett 1995), we did not sample zooplankton in this study.

This study provided new information on potential prey available to Marbled Murrelets in Año Nuevo Bay, indicating that night smelt may be an important prey for these birds in central California. More research is needed, however, on seasonal changes in local prey availability, and more importantly, on diet of Marbled Murrelets in California. This limited sampling did not provide data on interannual variability in prey availability and community composition in central California. Climatic conditions and corresponding changes in prey availability may substantially affect breeding success of Marbled Murrelets in California (Becker 2001, Peery et al. 2004). In addition, little is known regarding the basic ecology of night smelt in central California, or of the actual diet of Marbled Murrelets in this area. The central California population of Marbled Murrelets is at risk of extinction (Peery et al. 2004), and obtaining additional information on the species' diet and prey ecology is crucial in determining potential factors limiting population growth.

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[18]Op.Cit.
[19]Op.Cit.
[20]Op.Cit.

LITERATURE CITED

Ainley, D.G. and R.J. Boekelheide (eds.). 1990. Seabirds of the Farallon Islands. Stanford University Press, Stanford, CA.

Ainley, D.G., W.J. Sydeman, R.H. Parrish, and W.H. Lenarz. 1993. Oceanic factors influencing distribution of young rockfish (*Sebastes*) in central California: a predator's perspective. California Cooperative Oceanic Fisheries Investigations Reports 34: 133-139.

Anthony, J.A., D.D. Roby, and K.R. Turco. 2000. Lipid content and energy density of forage fishes from the northern Gulf of Alaska. Journal of Experimental Marine Biology and Ecology 248:53-78.

Beck, R.H. 1910. Water birds of the vicinity of Point Piños, California. Proceedings of the California Academy of Sciences (4th Series) 3:57-72.

Becker, B.H. 2001. Effects of oceanographis variation on Marbled Murrlet diet and habitat selection. Ph.D. dissertation, U.C. Berkeley.

Becker, B.H. and S.R. Beissinger. 2003. Scale-dependent habitat selection by a nearshore seabird, the marbled murrelet, in a highly dynamic upwelling system. Marine Ecology Progress Series 256:243-255.

Bodkin, J.L. 1986. Fish assemblages in *Macrocystis* and *Nereocystis* kelp forests off central California. Fishery Bulletin 84(4): 799-808.

Burkett, E.E. 1995. Marbled Murrelet food habits and prey ecology. Pages 223-246 *In* Ralph, C.J., G.L. Hunt, Jr., M.G. Raphael, J.F. Piatt (tech. eds.). Ecology and conservation of the Marbled Murrelet. General Technical Report PSW-GTR-152, Pacific Southwest Research Station, USDA Forest Service, Albany, CA.

Cailliet, G.M., K.A. Karpov, and D.A. Ambrose. 1979. Pelagic assemblages as determined from purse seine and large midwater trawl catches in Monterey Bay and their affinities with the market squid, *Loligo opalescens*. California Cooperative Oceanic Fisheries Investigations Reports 20:21-30.

Chavez, F.P., J. Ryan, S.E. Lluch-Cota, and M. Niquen C. 2003. From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science 299:217-221.

Dahdul, W.M. and M.H. Horn. 2003. Energy allocation and postnatal growth in captive Elegant Tern (Sterna elegans) chicks: responses to high-versus low energy diets. Auk 102(4):1069-1081.

Fitch, J.E. and R.J. Lavenberg. 1971. California marine food and game fishes. University of California Press, Berkeley.

Harvey, J.T., R.C. Helm, and G.V. Morejohn. 1995. Food habits of harbor seals inhabiting Elkhorn Slough, California. California Fish and Game 81(1):1-9.

Henkel, L.A. 2004. Seasonal abundance of marine birds in nearshore waters of Monterey Bay, California. Western Birds 35(3):126-146.

Henkel, L.A., E.E. Burkett, and J.Y. Takekawa. 2003. At-sea activity and diving behavior of a radio-tagged Marbled Murrelet. Waterbirds 26(4):9-12.

Love, M.S., M.H. Carr, and L.J. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus *Sebastes*. Environmental Biology of Fishes 30: 225-243.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game Fish Bulletin 57.

Morejohn, G.V., J.T. Harvey, and L.T. Krasnow. 1978. The importance of *Loligo opalescens* in the food web of marine vertebrates in Monterey Bay, California. California Department of Fish and Game Fish Bulletin 169.

Nelson, K. 1997. Marbled Murrelet (*Brachyramphus marmoratus*). In Birds of North American, No. 276 (A. Poole and G. Gill, eds.). Academy of Natural Sciences, Philadelphia, and

American Ornithologists' Union, Washington, DC.
Ostrand, W.D., S. Howlin, and T.A. Gotthardt. 2004. Fish school selection by Marbled Murrelets in Prince William Sound, Alaska: responses to changes in availability. Marine Ornithology 32:69-76.
Parrish, R.H., D.L. Mallicoate, and K.F. Mais. 1985. Regional variations in the growth and age composition of northern anchovy, *Engraulis mordax*. Fishery Bulletin 83:483-496.
Peery, M.Z., S.R. Beissinger, S.H. Newman, E.B. Burkett, and T.D. Williams. 2004. Applying the declining population paradigm: diagnosing causes of poor reproduction in the Marbled Murrelet. Conservation Biology 18(4):1088-1098.
Penttila, D.E. 1997. Investigations of intertidal spawning habitats of surf smelt and Pacific sand lance in Puget Sound, Washington. Pages 395-408 in Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant Program Report 97-01, Anchorage, AK.
Spear, L.B. 1993. Dynamics and effect of western gulls feeding in a colony of guillemots and Brandt's cormorants. Journal of Animal Ecology 62:399-414.
Van Pelt, T.I., J.F. Piatt, B.K. Lance, and D.D. Roby. 1997. Proximate composition and energy density of some North Pacific forage fishes. Comparative Biochemistry and Physiology 118A(4):1393-1398.

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